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ABSTRACT

Issues concerning the introduction of information technology in education were studied as part of a project sponsored by the Organisation for Economic Co-operation and Development (OECD). The following areas were explored: policies for schools and higher education and the context for the policies; implementation strategies; the impact on learning; the impact on teachers, teaching, and the curriculum; the impact on budgets, structures, and students; and possible futures. Educational responses to the challenge of new information technologies that have originated outside the formal educational sector are described, including programs for the general public and young people, and telecommunication-based projects. Strategies of policy implementation in primary and secondary education concern equipment, software, curriculum, and teacher training. Higher education uses information technology to provide computer assisted instruction and to deliver professional continuing education. Additional topics include: the impact of information technology on learning processes (reading, writing, and mathematics learning); cognitive prerequisites of computer programming; partnerships to promote information technology (e.g., between schools and universities); the use of technology in management and employment, and distance learning. (SW)

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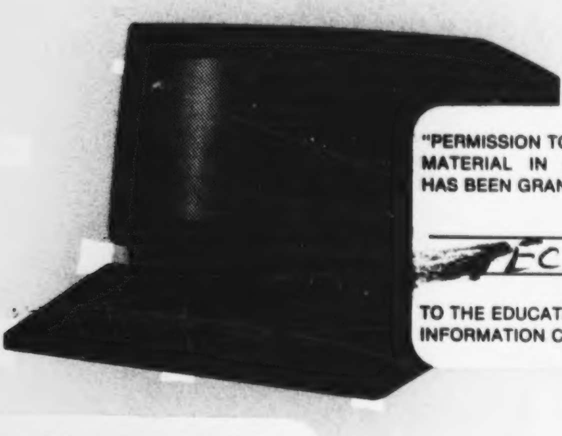
A CHALLENGE FOR EDUCATION



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NEW INFORMATION TECHNOLOGIES

A CHALLENGE FOR EDUCATION

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PREFACE

In July 1984, more than two hundred education officials and experts gathered at the OECD Headquarters for a four-day International Conference on "Education and New Information Technologies". This marked the conclusion of the first phase of a project launched by CERI two-and-a-half years before to clarify the issues inherent in the introduction of information technology in education and to set the ground for forecasts as to the future.

During this time, CERI staff members Pierre Duguet, Carla Fasano (now Professor of Education at the University of Wollongong, NSW, Australia) and Pierre Laderrière, working in close collaboration with government officials and experts in Member countries, had been analysing a large amount of contributed information on ongoing developments in policies, strategies of implementation and research. The results of this work were presented at the Conference in a series of studies, examining a range of topics from policies to programmes; from learning processes to applied research; from curriculum development to cost estimates. Formal education sectors from primary to higher education are covered, as well as informal programmes.

A selective approach has been adopted in this report, focusing on what is concrete rather than speculative and on large-scale impacts and implications rather than technical detail, with a view to the most pressing needs of policy-makers and those who must take the decisions.

Here, then, is a distillation of current informed thinking on some of the more fundamental questions taxing the minds of social and educational planners – not the least of which are: What is the real potential of information technology for education? What is the relationship between developments in education in this field and developments elsewhere? What are the costs involved (financial and otherwise) for education and its clients?

From this rich background the report, which is published under the responsibility of the Secretary-General, has been prepared by Carla Fasano as a summing up of the work under the first phase of the CERI Project. The second phase, already begun, concentrates on the present and potential role of new technologies in enhancing teaching and learning with a specific focus on basic skills at the compulsory education level.

J.R. Gass
Director
Centre for Educational Research and Innovation

Chapter I

POLICIES WITHIN A CONTEXT

Over their hundred years of life, formal systems of education have seen many changes: the current revolution in information technology is pressing them towards yet another. Once again, then, the question arises as to how education can or indeed should respond to the challenge and at what cost.

By mid-1984, virtually every industrialised country had accumulated experience, achievements and doubts on this question. Their contributions to the debate – illustrated in detail in the subsequent chapters of this report – are as numerous as they are varied. In each country, the educational market has been witnessing the proliferation of technology-related provisions and programmes initiated by a large number of agencies, public and private, formal and informal.

The combination of these co-ordinated and haphazard initiatives, all reflecting particular expertise, motivation and interests as well as different histories of past experiences, result in provisions that are exceedingly varied within as well as across countries. Their content and scope are composite, their degree of co-ordination is as diverse as their administration and juridical status, as the patterns of roles and responsibilities therein.

At face value, the patchwork is intriguing. Regardless of their mutual contrast, each one of its constituent parts is heralded as an educational response to the same challenge: that implied by the new information technologies entering the production and service sectors of the economy, penetrating all spheres of society, down to the ordinary, routine, everyday life of people. Seldom in the past have educational responses to an – allegedly – same demand been so dissimilar from one another.

How shall we interpret the present situation? Doubtless time will tell. Given time, the situation will obviously solve itself. Yet, to paraphrase Joseph Weizenbaum (1983), wherever we are going, it would be wiser not to find ourselves there by accident. Our contribution to the avoidance of this must first depend – *inter alia* – on the clarification of a number of key issues. Among them are those concerning the very origin of today's developments. Education has been late to enter the new technology market. By the time it did, in the early 1980s, the context and the conditions of the encounter had already been set by forces and interests as powerful as they were related only occasionally to educational preoccupations and needs. To understand the current response of education to the technology it is indispensable to consider these developments first in order to identify the actors and factors that have most influence on them and appear to be strong enough to keep playing such a role in the future.

THE CONTEXT

The context within which educational responses are developing is one where technology itself has had the time to develop since the early 1970s – when the "silicon chip" revolution began – and diversify in line with the possible demands of the most profitable markets. Few of these had – or for that matter have – a recognisable educational connotation. The outcome has been a profound impact on the economy (imposing new labour policies and new ways of working), on the production and diffusion of information, on the development of new services, and of new forms of culture and of consumerism.

These developments across sectors have not failed to influence the reaction of education to the same pressure for change. Education is itself at the crossroads of a number of markets, where many visible and intangible goods and services are produced and traded. This has given it a great strength as part of the service sector, but has also rendered its relationship with the new information technology particularly complex and especially delicate.

Much of education is about information-processing. In that much, the new technology can be expected to have an important impact on the processes, markets and structures that make up the organisation and delivery of the educational service. Education is also about the definition and transmission of knowledge and skills, of social as well as personal meaning. Therefore, unavoidably, education is fully invested by the demands and implications of the technology on social life and organisation as well as on the definition of culture.

Much of education is about the economy. In that much education qualifies as a market for the new goods and services as well as a factor of production for the new demands on manpower training. Education is also about politics and government. It is therefore part and parcel of national policies, inextricably linked to the countries' imperatives on industrial development and commitments to social justice, as well as of international policies concerned with patterns of dependence – economic and cultural – between countries. Finally, much of education is about its own survival as an institution. In that much, it has to face the challenge of the new technology on its structure and organisation, already faced by other sectors of the economy.

The Growth of Information

The media have made the public at large all too familiar with the different forms taken by the new information technologies and there is no need here to list once more what is available on the market, nor is it necessary to spell out in detail what is in store in research laboratories, the many applications of artificial intelligence, the new generation of super-powerful and super-fast computers, which will amplify yet more the process of change already well implanted in society.

In an analysis of educational implications, we need not concern ourselves with the technicalities of hardware or software so much as their impact on man and his immediate environment. This technology is about information-processing, about translating instructions into actions, about memorising and communicating – which is what humans mostly do. In a man-made and man-inhabited environment, this specificity makes it highly and pervasively relevant to a large number of human occupations (and pre-occupations), in ways we only start to fathom.

Its influence cannot but grow larger – on markets for goods and services and, perhaps less visible but no less important, on the processes behind the outcomes. The introduction of the new tools and techniques in the workplace is altering the labour market in a number of ways – not least in the redeployment of whole sectors of the workforce and the re-equipment of some with new kinds of skill and competences, more directly related to the requirements of the new production and delivery processes. New bodies of knowledge and new learning needs are similarly emerging in society at large, based on information produced and made available in ways which reflect – unavoidably – the technical possibilities and demands of the carrier.

With its responsibilities for defining and transmitting knowledge and skills to the population, education must be fully concerned with this process of growth and the implications of the many questions that arise in the course of it. Who, for example, produces this information and what for? What is its content, its structure, its meaning, its relationship to existing culture? How does this information travel across national borders? To what extent is the new technology a way to break down existing constraints in communication and control of information? To what extent does it introduce new ones? How is the existing universe of information reproduced, influenced, distorted by its technological carrier?

The information carried by this technology is not just "any" information. As with older technologies, this new one suffers from the same unavoidable limitation: it carries only the information it "recognises", i.e. that which can be coded within its own particular system. What is paramount to note for educational purposes is that mere technical codability of information by no means ensures that it has a meaning.

For the technology, information is not just any fact or data, meaningful or otherwise; information is only that which can be processed as signals. Facts and data that do not transfer or travel, that are not amenable to fit its coding and decoding system, cease to exist, as it were, for the receiver. Images that do not bend to a proper recording technique do not survive across the barriers of time or space, nor do words or sounds. Put plainly, the information growing with the diffusion of the new information technology is only that which can be represented by a binary code and processed sequentially. The universe of all possible information is of course much larger than this. The forthcoming progress in analogical and "parallel" information systems will no doubt enlarge the size of the "codable" subsection of the larger information universe, but it still will not close the gap. The information carried and exchanged within a variety of human interactions, for example through touch, taste, smell or body language, to name but a few things difficult to reduce to strings of digits, will no doubt remain "unfittable" to this technology – at least for some time.

Within its boundaries, however, the new information technology can be very powerful indeed. Paradoxically, its strength rests on its very limit: its coding system. The simplicity of the binary code gives an exceptionally high degree of flexibility, and its non-specialised nature makes its application possible in a large number of human activities, helping to overcome a number of constraints of time, space and power. Society is therefore fully "penetrable" by the new technologies, according to modalities and consequences that are, however, only just emerging.

The speed of diffusion of the new information technology makes many anticipate the possibility that the corpus of information thus created might soon come to be the largest portion of the information generally available to the public at large. The important issue remains, then, to understand the modalities of growth of such information and to monitor its development so as to master the consequences on the definition of the body of knowledge that is at the core of society as we know it. The role and responsibility of education in this respect are indisputable.

The Cultural and Existential Concerns

Part of the information carried by the new information technology is about itself. No more than fifteen years ago, electronic-filled scenarios belonged mostly to fiction or laboratories invisible to the general public. For the layman, they lived mostly on screens and printed pages, symbols of magic power, of surhuman potency. At present, they have entered the reality of us all, our homes, our workplaces, our banks and post offices, our railway stations and airports. Increasingly the purchase of a microcomputer or of additional terminals is entering family discussions. Patiently, customers are learning to communicate with various services through some technologies. In most cases the reaction is the same: a duality of appreciation and apprehension. Are the technologies a threat to privacy, to democracy, to humanity? Are they a better way to ensure privacy, democracy, humanity? Is technology just a means to an economic end? Is it a support to culture? Is it culture? Shall all people learn about them or by them? How much knowledge is there to acquire? By what means? At what costs?

Had we lived long enough we would remember that many times similar debates have developed around other important breakthroughs. Mechanical power, hydraulic power, steam power, electric power have all changed the way people live and think several times over. In many respects, the hopes and the fears expressed over the centuries in similar situations have not changed. Past experience can then suggest answers to the questions raised once again, but only to an extent. The current technological developments, together with the other major development of this century, nuclear technology, present humanity for the first time with the possibilities – unavailable so far – of total control, for good or evil, and total destruction.

The specificity of the situation does not necessarily change the nature of the questions raised; but it makes the need to find suitable answers all the more acute and all the more pressing. In this context, the debate around the technologies acquires a peculiar tone of urgency, for it liberates a central, and very ancient, concern: the relationship between man and his (technological) creation. Works of art are seldom perceived as threatening to humanity except in very specific ideological contexts. But any new scientific and technological breakthrough seems to evoke the same centuries-old interrogation: will the new power released by man to his benefit escape control and turn against him?

In terms of education this basic existential concern is best illustrated by the never-ending debate about the two cultures: the humanist and the scientific, supposed to produce different learning, different thinking patterns and in the end individuals rather alien to one another, with the "scientists" caricatured as more vulnerable to "technological bewitchment" than the "humanist". Back in the 17th Century, Blaise Pascal had already written on the difference between the "esprit géométrique" and the "esprit fin" and the lack of communication between the two.

The relentless progress of science and technology has made the debate only more acute and, by this century, definitely worrisome after the nuclear events of the second World War. By then the issue had taken a definite political connotation, encapsuled in the words of C.P. Snow: "It is dangerous to have two cultures which can't or don't communicate. In a time when science is determining much of our destiny, that is whether we live or die, it is dangerous in the most practical terms. Scientists can give bad advice, and decision-makers can't know whether it is good or bad. On the other hand scientists in a divided culture provide a knowledge of some potentialities which is theirs alone. All this makes the political process more complex, and in some ways more dangerous than we should be prepared to tolerate for long, either for the purposes of avoiding disasters, or for fulfilling ... a definable social hope." (C.P. Snow, 1959)

Under the impact of the new information technologies, the debate around the two cultures has taken new momentum, often spiralling along three escalating concerns. Will their widespread introduction in all spheres of society increase the cleavage between the two cultures? Will the "technological" culture become predominant over the "humanistic"? Will the source of influence on culture and learning shift then from the "technicians" to their machines?

It is not difficult to perceive these kinds of existential concerns underlying issues such as the necessity or desirability of a new kind of literacy involving computers and other technologies: hence the debate about the cognitive demands this might entail, the new cognitive make-up needed to become literate in order to draw benefit of a more general cognitive nature or to protect oneself from it. The evidence put forward by some authors on the divorce between planners and users adds to the concern "...the influence of users/clients has not been found in most systems design. Typically, the technology has been introduced in such a way that planning and operating have been separated. The system planner defines the need for information, designs the system, handles the programming and implements the system. The user is often an astonished spectator." (Bjørn-Andersen, 1981, p.50)

On bases such as these turns also the issue of the feasibility and, again, desirability, of introducing the new technologies into education as a learning tool in disciplines other than scientific or technical. The survival of human characteristics vaguely subsumed under labels such as creativity, lateral thinking and the like, are the stakes implicit in (technical) debates on, for instance, computer languages, software authorship techniques, computer-based simulation or the use of electronic data banks.

In each case the question is raised as to the degree of distortion introduced by the technologies in the representation of the world or of the man-built knowledge transmitted by them to the learner. In each case, attention is called to the consequences for the learner of emphasizing the growth of logical patterns, of privileging the acquisition of cognitive skills that risk reflecting more the specific nature of the electronics underneath than the overall possibilities of the human brain. In short, by defining themselves as alternative gateways to the acquisition of knowledge and skills, the technologies are indeed introducing the possibility of new sources of influence on what is learned, how and to what purpose.

To the extent that they are man-made, the technologies have the potential to operate in directions established and controlled by man. But man does not know nor master all the processes to which the technologies are or could be applied. The gathering and diffusion of information, its selection and organisation, the functioning of the human brain, the evolution of human needs and desires, to mention but a few likely candidates, are processes still ill-defined and not clearly understood. The impact of the new information technologies in such areas can have unforeseen effects, of positive as well as less positive value, as they can release forces and steer processes still elusive to the human mind.

These kinds of concern have been formalized by a number of authors, especially in so far as they relate to the effects of the technologies on the development of human personality, in general, and on human thinking in particular. Broadly speaking, a consensus has emerged that such an influence is a real and unavoidable possibility. A report (Ruoppila, 1983) shows how far back one can track the evidence that radical technological change affects the way people think, by way of influencing the formation of concepts in a language (e.g. Vygotsky, 1962) or the construction of one's identity (e.g. J. Weizenbaum, 1976). Seymour Papert makes it a central point of his development of the LOGO learning system: the approach to computers involves more than just the question of "what can one do with it?"; it means the consideration of the ways in which one might be changed by using it, of how one's way of thinking could be changed or the ways one learns (S. Papert, 1980).

While most seem to agree on the likelihood of the impact, less consensus exists as to its nature. Some, like J. Weizenbaum, put forward a strong warning as to the possible harmful effects of the technologies on the preservation of what makes man human. His central argument is that people are influenced by computers to a very considerable extent in their body and linguistic expressions. The computer can become part of a person and alter his way of comprehending reality. Computers will affect the way people look at themselves by becoming part of their identity. Others, like H. Simon, are less pessimistic, but for different reasons. In Simon's view, it is not so much the power of computers that might be at the basis of a reduced humanity as the fact that human personality is in itself "reduced": "Human beings, like ants, have very simple behaviour patterns. The apparent complexity of their behaviour is basically only a reflection of the surroundings in which they find themselves." (H. Simon, 1969)

These claims are far from the almost mythical approach of S. Papert and his followers to the potential benefits man can draw by using computers to enrich learning environments. They are equally at variance with the claims of authors such as the French J.C. Simon identifying the "culture of informatics" as "the final achievement of our modern culture, technical and intellectual at the same time" (J.C. Simon, 1980). This dual nature of uncertainty on the "existential" impact of the new information technologies could be illustrated by a multitude of quotes from a variety of authors. The overall pattern would not change by much. It would still reflect, on one hand, a familiar – and basic – disagreement over "models of man" (the "humanistic" versus the "mechanistic" approach) and, on the other, the novelty of large-scale encounters of people with the new machines and little or no clearly-documented information on their reactions.

The issues raised from the existential viewpoint show a certain degree of coherence in so far as they reflect the same belief: the new information technologies can have an influence on the ways man defines himself and functions, on what he can learn, how and to what purpose. In the absence of clear-cut positions as to their actual effects it becomes particularly important, however, to assess the extent to which, when introducing the new information technologies in the realm of learning, one could still retain control of the unknown. In other words, the uncertainty on the outcomes makes it all the more essential to focus on the process, to what can be called matters of organisation – the ways in which the influence of the technologies are or can be brought to bear on their target. The cultural and existential debate thus sets, rightly or wrongly, some first items for the educational agenda: whatever its response to the technology, education has to ground it on a clear awareness of the impact of the technology on learning and on the understanding of its consequences for life, personal and social.

The Demands of the Economy

Like any other service, education uses tools manufactured elsewhere. The most immediate relevance of education to the economy is thus as a buyer. Theoretically, all forms of information technology are relevant to education, yet education's role as a buyer has been so far limited in quality and modest in quantity. The subsequent chapter analyses in some depth why, of all possible technologies, only the computer is entering educational establishments and why, among its multiple forms, the microcomputer – the smallest and cheapest of the family – is being bought in largest quantities. More rarely one finds minicomputers, or link-ups with electronic networks. Infrequent also are composite terminals including videodiscs or accessing mainframe computers.

This early positioning of education, and especially of general education, in such a specific sector of the information technology market does not go without consequences for the actual use of the technology. It sets boundaries to the "computer power" thus available, in terms of both hardware and software. It therefore limits the "pedagogical power" it can be translated into. Whatever the response of education to the technology, it will not escape being framed within these constraints.

Next to these "direct" limits, another boundary comes, indirectly, from the relative importance of education with respect to other buyers. A number of market analyses converge in saying that education is, and will remain, a marginal sector of expansion in the microcomputer market, compared to medium and small businesses (so far the largest sector) and the home, expected to take the lead in the near future (Charles and Dyan, 1984). As there are therefore limited profits to make out of educational products of good enough quality to appeal to education, it is unlikely that these goods will be produced in any large quantity by the private sector. This means that education has not qualified, and in all likelihood will still not qualify, as a priority area of R&D investment on the part of commmercial producers. A chief consequence for education of its marginality as a consumer will be a stronger strain on its resources. Whatever the R&D effort needed to produce the educational applications of the technology that are desirable, it will have to come, in all likelihood, from within education. This will impose an additional constraint on the educational response to the technology.

In her opening speech at the Conference, the Hon. Bette Stephenson set clearly the terms of the relationship linking education to the economy through the double issue of the new manpower, who need to be trained in new technology-related skills, and the established labour, for some of whom the issue of retraining is at times indistinguishable from that of displacement and unemployment. In her words, "it seems unlikely that the traditional sectors of the economies of the OECD countries will grow, in general, at a rate which will compensate for the attendant displacement. Structural unemployment is therefore a reality. Surely, we are much more likely to deal with it effectively if we approach it through thoughtful restructuring of our work and social patterns and through search for renewed economic growth in new sectors of the economy, than we are if we insist upon repeating the tired formulae of the past. These circumstances force another set of challenges for the education and training systems. As the rate of change and the rate of displacement remain high, the need for retraining, on a permanent life-long basis will be evident as it has never been before. That training must be highly flexible, quickly mounted and rapidly responsive to changing needs dictated by changing technologies."

Few would disagree on either the need or the guiding principles expressed in such a statement. The issue is rather the lack of understanding and consensus as to specifics of the educational response in this area. Among the terms of the debate, those that have the strongest influence in shaping the response of education to the demand address the issues of quality, quantity and timing; in other words, the uncertainty as to the definition of the new skills, the size of the cohort needing training, and the evolution of both in the medium and long term. On the first point, a recent analysis summarises the situation cogently:

> One of the most important findings is that new technologies are, by themselves, unlikely to determine the content of jobs and a new structure of skills. They will, of course, influence them but they leave plenty of room for new work organisation to be introduced by people and groups affected by change. As a consequence, *there is no technological determinism*, meaning by this a simple, direct, one-way relationship between new information technology (NIT), the structure of skills and training needs. Forecasts of NIT-related manpower needs are, therefore, of little value. They should only be considered as elements in the general framework but not as vital targets taking the place of more elaborate education and training policies.
>
> There is currently a wide range of divergent opinions about the implications of NIT for education and training. Thus, no consensus exists yet on the minimum level of qualification required by users of NIT. According to some observers, NIT require most of all abstract, theoretical thinking, creativity, communication abilities and willingness to participate in teamwork. Basic, general education may be in a better position than technical or vocational education to develop these skills and it is therefore often proposed to introduce basic NIT knowledge into the basic education curricula. But, according to others, care should be taken not to divorce NIT knowledge from actual NIT practice in firms, which calls for an increased role of vocational training closely linked to firm-based training (Jallade, 1984).

Another author (Bjørn-Andersen, 1981) emphasizes the influence of non-technical factors in shaping the definition and organisation of skills for the new workplace, and in particular the impact of political/economic, ethnical/moral and epistemological factors through shifts in the organisation of structures of control, communication and task allocation, vertically as well as horizontally.

As to manpower forecasts, the trends just emerging (Jallade, 1984), (Frey, 1982 and 1983), (Riche *et al.* 1983) point to at least a tripartite categorisation in the evolution of skill demands which is expressed, at best, only in qualitative terms. Most analysts agree that the number of high-level specialists is smaller than anticipated by popular belief and is likely to remain so. Consensus is also spreading on the emergence of another, and larger, category of skills, that of the professional "appliers" needed in both industry and services sector, characterised by a "double qualification" where additional and "technology-related" skills need to be acquired alongside those of established trades and professions.

A third, and much more nebulous category is that of the "users" of the technology, both on the job and off it. These are expected to have enough skills to be able to use the technology without any in-depth knowledge or understanding of them. The generality of such definition makes this category of people the largest in the populations list and the easiest to accommodate – at least at face value – in a variety of educational provisions, formal and informal, in and out of schools.

This categorisation differs from the taxonomy usually applied to the vocations already getting their own tailor-made responses from the education system, and the new occupational groups will no doubt require their own special treatment. This would constitute yet another "vocational demand" by the industrial/economic sector which the educators would have to face up to.

Pressures from within Education

The "conceptual overlap" between the nature of the new information technology and the process of delivering and acquiring knowledge makes its products especially relevant to the teaching/learning process. Moreover, its versatility enables it to perform equally for the managerial and the pedagogical function. Thus it holds a great potential for functional transformation. In the words of Mrs. Stephenson, "just as the immense communications and informations processing abilities of computers transform most processes of which they become a part, so does the computer transform the nature of education and the functions of teachers and schools". Lariccia and Megarry, in their discussion paper (see Bibliography, Part A), have made the challenge to the organisation and delivery of education more explicit:

> Traditionally, formal education has been delivered during fixed hours, in pre-determined places, with courses beginning in fixed months of the year. Previous qualifications are sometimes demanded, and there may be age restrictions. NIT calls all of this inflexibility into question. Given suitable equipment – e.g. a cheap microcomputer, standard television, telephone and modem – there need be no artificial barriers to learning. Why should not the elderly, the disabled, those in ships or prisons, people on remote islands and mothers housebound by infants all have access to the same courses and examinations as the stereotype of the 18-year-old mobile bachelor for whom residential university education is traditionally designed? Naturally, some educational objectives require attendance at some kind of local centre ... but once the possibilities of NIT have been fully understood, it is remarkable how few of the conventional restrictions can be defended rationally, and what a high proportion of needs can be accommodated on a flexible basis offering more convenience to students.

Le Corre and Schwartz have commented on the other side of the "functional" coin – the potential of the technology for increasing productivity. "The rapidly advancing electronic technology of information processing and display offers many potential advantages to the educator. Most fundamentally, it may allow the steady rise of educational costs to be moderated, through partial replacement of the artisan-like work of teachers labouring in individual classrooms to a more highly profitable system able to make effective use of powerful tools. Failure to deal successfully with the issue of productivity in education must inevitably lead directly to reduction in the real income of teachers, followed by declining student achievement and lagging economic growth. Computer technologies can improve productivity in education."

The arguments are convincing enough. As it has done for other sectors of the economy, the technology can make the delivery of the educational service more efficient. Obviously, it would not be easy nor costless for education to embark on far-reaching reshaping and transforming, as achieved elsewhere; yet the potential benefits are such as to make the efforts worth investigating.

Some of the constraints to a proper and full exploitation of the potential of the technology for education are likely to come, not unexpectedly, from within the system itself. As an institution, it has a particular talent, shared with other agencies of comparable age and size: it inclines to resist change, indiscriminately. So, this "natural inertia" can safely be expected to dampen the vigour of the institutional response to the new challenge. Additionally, the specific potential of information technology itself is likely to raise some alarms and obstacles.

A first and major preoccupation in education comes from its own manpower. In a world where the largest item in educational budgets is "teachers' salaries" and where educational expenditure has been in a state of slackened growth for several years without showing any significant sign of recovery, it is no surprise to find doubts of an industrial nature among those employed in the system. What is known or hoped for in pedagogical terms does not entirely dismiss the apprehension that the new technology will become a threat to employment. As in other sectors of the economy, the introduction of information technology in education will not escape pressure from the teachers.

A second major determinant of the response of education to the technology comes from its timing. The challenge of the technology comes at a time of crisis for most education systems. Demographic changes, financial stringency, unemployment, adverse public opinion, all impinge in creating an environment of criticism and a pressure for change, at all levels of education, for schools as well as universities. Few of the countries are likely to be in a position to tackle the "technological" issues serenely for some time. Few of the decision-makers in education will be spared the temptation to consider the technologies narrowly in relation to the crisis (in terms only of their potential for solving the crisis), rather than broadly in relation to education nationwide.

Faced with such an array of obstacles, education could very well be tempted to resist the demand for "technological change". Yet it is debatable whether this attitude can be allowed to prevail. Education can hardly ignore the outside pressures for change: as part of the service sector, it is invested with the same imperatives as the economy as a whole, and may be forced to adapt to the new technological world in order to remain financially viable. Next to the economic argument (which educators could reject on the grounds that the performance of education cannot be evaluated exclusively in financial terms) is the reality that education cannot ignore any large-scale social change without running the risk of losing legitimacy as an institution and credibility as a service. Failure to meet the challenge could only result in the world outlined by Bette Stephenson at the close of the Conference:

As most of us are aware, the traditional formal educational and training systems are not particularly noted. But they must acquire those talents or suffer total replacement by newer, more rapidly adaptive systems. One could indeed suggest that the new technologies themselves provide the best means of coping with new training needs; flexibly deployed in home, office, factory and shop; rapidly developed as new needs become apparent; highly adapted to individual learner needs and significantly self-paced. One can imagine some of our established institutions evolving into such a role; indeed some already have; one can imagine others declining quietly into increased irrelevance and ultimately succumbing to total atrophy.

While one can visualise the evolution of certain institutions into a species of central "service" bureau for a widely dispersed, flexible and informal training system I would not wish to imply that all of formal education can or should be reduced to a body of specific knowledge and skills whose acquisition the computer can facilitate. To the extent that true education goes far beyond such definition, to the extent that our educators are able to utilise the new technologies for the excellent pursuit of valuable purposes and are willing in their own efforts to extend well past the mere mechanics of their calling, therein lies the deep and largely unexplored area which is the important future for formal education.

THE POLICIES

Changes in productivity, creation of new goods and services, integration of services and production, redefinitions of markets and structures, restructuring of the labour market and reshaping of cultures: the impact of the new information technology is unprecedented in content as well as scale. Patterns of communication are changing, new bodies of knowledge are emerging, new skills are demanded, constraints of time and space are receding. Whether all this is happening positively and directly as a result of the active application of the new micro-electronic technologies, or negatively and indirectly as a result of failure to apply them, the impact is and will be inescapable.

The range of impact on society and the growth of contextual forces and concerns explain why, at the beginning of the 1980s, the response of education to these technologies took the only form commensurate to the challenge: that of policies nationwide. By now, a few years later, all OECD countries have made progress in introducing them in education. In a number of these countries, experience has been accumulating since the beginning of the 197Os, when essentially main-frame computers were first used for educational applications. No clear-cut consensus emerged then on the educational advantages of using these instead of "softer" teacher-based methodologies. During the past few years, and essentially under the impact of the new generations of computers – the mini and microcomputers – the educational involvement in the area has taken a new momentum in all countries. The alleged reasons are the cost/performance ratios of the new hardware, more favourable than in the past, its potential for flexible and interactive use, its size, small enough to fit ordinary educational settings. At present, in a large – and increasing – number of Member countries, the developments have become important enough to warrant viewing the introduction of information technology in education as an object of co-ordinated development programmes, nationwide, under the responsibility of the public authorities.

The quantitative trend, common across countries, feeds on similar underlying principles, materialising in different forms taken by the new initiatives. The variations concern the policy approaches adopted as well as the scope given to the technologies in education, the roles and responsibilities taken up by the educational institutions in charge, the optimal target groups identified in the school population, the curricular innovations deemed most appropriate and the human and material resources invested. With the acceleration and diversification of the responses, the trend has also undergone a qualitative change. Ten years ago, the forces underlying the educational responses to the technology were essentially educational. At present they have expanded to include pressures often foreign to education. As already discussed, these pressures come essentially from the evolution of the economy, the penetration of the technologies in all spheres of society, the imperatives of international trade, increases in the responsibilities of education with respect to the labour market, the evolution of the educational technologies themselves towards increased differentiation and specialisation, and the emergence of a (sometimes blind) constituency in favour of the introduction of information technology in education.

Currently, these developments, common to most OECD countries, have converged to pressurise education towards objectives that are not necessarily compatible nor complementary to one another – such as introducing the NIT into the system, at points and for purposes dictated by the economy. For example, to produce specialised manpower and to develop a market for the national (multinational) electronics industry; to prepare the young to be functional in a society permeated with the new information technologies; to better the functioning of education (e.g. with systems for special population groups); to improve the efficiency of the education system in general, to reduce its costs (with or without improving its efficiency); or for purposes of political visibility, e.g. to build a public image of governments changing the schools to the new image of the world.

Taken separately, each one of such pressures has clear – and different – implications for educational policies, on the targeting of the policies on specific education sectors and population groups, on the scale of investments, on the equipment policies developed, on the curricular changes introduced and on the demands on the teaching staff. The issue is how the authorities in charge react to the web of influences, how priorities are allocated across objectives, how resources are supplied, what strategies of implementation are adopted; in short, how roles and responsibilities are defined and distributed in the public sector as in the private one.

Policies for Schools

If the pattern of these pressures is somewhat similar across the OECD area, their interrelationship, and in particular their relative weight, remains essentially country specific. The economic argument is currently prevailing in some countries, in others the lead has been taken by the educational concerns, in others still, the educational responses are reflecting more of the existing political necessities. Only a few of the countries are developing policy approaches responding to most of the pressures at once. The broad objectives are similar across countries. Most of them recognise NIT as holding a great potential for education. But they do not necessarily take the same stance as to the specific contribution it might make: whether it is to be included in the body of knowledge all citizens should have in order to function in society, whether it is a matter to consider solely in terms of vocational education, whether it holds a beneficial potential to the institution of education more than, or as well as, to the learner.

While virtually all policies establish priorities, they sometimes differ as to the entry point into the system. Policies for primary and secondary education can often be accommodated in a taxonomy. The first family defined in terms of the educational lines affected covers two main groups of policies. The "vocational" group, most common in Member countries where the vocational education tradition is very strong, aims at introducing the NIT in vocational (commercial and technical) education leaving only a marginal "technological" budget for the general education sectors. The "comprehensive" group of policies, on the contrary, does not privilege one sector over the other. Policies of this kind are more common in countries where the vocational and general education sectors are formally merged within post-compulsory provisions or where the vocational tradition is not particulary strong within formal education.

A second broad classification of policies can be defined in terms of the priorities established for public investments and responsibilities by "front". Whatever the educational line adopted, the introduction of the NIT involves developments at different levels, such as equipment, curriculum and software and teacher training.

What now follows gives an overall picture of the situation in Member countries as observed at the beginning of the 1980s. Far from being static, the picture continues to change in most countries at a speed which makes it difficult to keep analysis up to date. Broadly speaking, the current trends, while confirming the taxonomy, indicate an evolution in membership. Some of the countries, in particular, seem to shift from one category to the other according to number of modalities. An example is the shift from "comprehensive" policies, on paper, to "vocational" ones in practice, observed by the mid-1980s in countries where the limited resources available for the implementation of the policies make it imperative to choose among stated priorities. There is also a shift from "equipment", "curriculum" and (inversely to the above) "vocational" approaches to more "comprehensive" ones in countries reaching further stages of development in this area. The examples given here have therefore to be considered only as indicative of possible policies and possible developments.

a) The "vocational" approach

In a number of OECD Member countries the primary response of the education system is to the demand for specialised manpower. The entry point for the NIT is, in these countries, the vocational sector. The policies developed have touched to a larger or lesser extent upon equipment strategies, curricular issues – including software production – and teacher training concerns. The speed at which the NIT penetrate from this to other education sectors varies by country, but the overall pattern is similar. The NIT expand from the upper years to the lower ones, more often than not never reaching the primary level.

In Japan, the speed of diffusion is at its lowest. The vocational education sector has been the first, and so far the only one, equipped to needs. At present all the vocational schools are fully equipped with an average of six computers per school. The rest of the secondary schools will follow on the policy agenda. There are as yet no plans to introduce the NIT at the primary level in any co-ordinated way.

In 1983, the situation in Austria was similar. Most vocational schools were already equipped with microcomputers at a ratio of between two and twelve micros per school and a cost of over Sch 150 million over three years. Only 40 per cent of the other secondary schools were then expected to be equipped by 1985, with a more modestly planned expenditure of Sch 5-6 million per year. No plans existed for the primary education sector. By early 1984, the plans for all secondary schools had become more ambitious. The planned expenditure had been raised to Sch 20 million per year for a targeted equipment in 1985 of all general secondary schools (years 5-12 or 9-12).

Other countries have adopted similar policy priorities. Finland will invest Mk 13-14 million a year (of which over 11 million as State aid) to bring its vocational schools up to needs by 1988. The other part of the upper secondary level will follow, although at a slower pace. Nothing is foreseen for the comprehensive schools. Belgium has recently launched a five-year plan aiming to introduce computer science in all vocational and secondary schools.

The cost will be around BF 500 million. Norway has given priority to its vocational education before involving the other branches of its upper secondary education. Note that the vocational institutions are the only ones in this country's education sector to receive financial subsidies from the State to purchase equipment, although the 1984 White Paper on "Computer technology in the school" recommends that such subsidies be expanded to other education sectors. The plan which followed the White Paper is scheduled to run from 1984 to 1989. In 1984, NKr 11.3 million was allocated to the selected schools. Having started with vocational education, Luxembourg plans to equip all secondary schools by 1986 with an expenditure of LF 60 million. No plans are made for the primary level of this country either. In the Netherlands, the revised funding in 1985 for the education section of the Information Science Promotion Plan ("IT Promotion Plan" which will run for five years, 1984-88) amounts to Gld 325.6 million, coming from the Ministry of Education and Science (58 per cent) and others, such as the Ministry of Economic Affairs and the Ministry of Fisheries. The majority of this budget is earmarked for the vocational sector. Most of the Mediterranean countries, for example Italy, have adopted the same approach, although in Greece, Portugal and Turkey their achievements remain in general more limited.

b) The "comprehensive" approach

The most telling examples of policies responding to most of the existing pressures are those developed in France and the United Kingdom. In France in 1983 the government had set clear objectives for the introduction of the NIT in education. It is stated that informatics should be part of general education for all; the NIT should be used to innovate at all levels of education and to make teaching more effective; the NIT should be introduced to renew and update vocational and professional education. In January 1985, a very ambitious plan called "Informatics for All" stipulated a further objective: school equipment should also be made available to the rest of the population. The plan, the total cost of which, including teacher training, comes to FF 2 billion for 1985, was launched on the responsibility of the Prime Minister.

If the highly-centralised nature of the French education system has certainly been a facilitator to implement such policies, with teacher training, educational experimentation as well as software production (the development of just the author system, DIANE, represents an investment of FF 14 million over two years) sharing resources fairly, the decentralised nature of the United Kingdom system does not seem to constitute a major impediment to implementing what is a rather similarly "comprehensive" policy approach.

In 1980, the Department of Education and Science for England, Wales and Northern Ireland launched the Microelectronics Education Programme (MEP), involving an annual expenditure of about £4 million. A year before the Scottish Education Department launched their own programme with roughly similar objectives and a quarter of the investments. Both projects serve typical educational concerns. They aim at: providing information and advice to all schools through a number of regional centres; assisting the relevant educational bodies with intensive courses of teacher training; developing curricular material, software (the MEP allocates about £60 000 per year to the regions to encourage software production) etc.; encouraging the pooling and the distribution of software. MEP will be considered in more detail when we come to the impact of the new technology on Administration (Chapter V).

Canada offers other examples of "comprehensive" policy approach to the introduction of the NIT in education, at least in some of its provinces, such as Ontario or Prince Edward Island, where hardware, software, teacher training and curriculum development are all part of the same policy agenda.

In Australia, in June 1983, the Commonwealth Government set up the Computer Education Program, committing A$ 19.5 million to support secondary schools nationwide throughout 1984-86. The Commonwealth Schools Commission, in its "Recommendations for 1985", recommended the allocation of an additional A$ 4 million to extend the Program to primary schools.

There are signs in 1985 that some countries are shifting from the vocational to the comprehensive approach. Italy has launched a national plan for the large-scale introduction of NIT in schools. The aim, according to the Minister of Education, is not simply to make computer studies part of the general curriculum, but to use NIT to change the content of the subjects taught. In April 1985, the Japanese Ministry of Education attributed a sum of Y 2 billion to assist the introduction of the computer in public elementary, junior and senior high schools, and schools for the handicapped. In Portugal, a still modest plan, called MINERVA, starts in the school year 1985/86, initially covering 50 secondary schools. Esc 700 million has been provided by the Ministry of Education and the Commission for Development of Information Technologies. The objectives are: to develop teaching about computers and learning with computers, with adequate teacher training. The same objectives are pursued in Spain, where the ATENEA plan (1985-1989) will provide equipment for 2 300 schools. Ptas 6 500 million will be made available for hardware, software development and teacher training.

As for the second entry to the taxonomy, by "front" of investments, one would find policies classified, theoretically, under four broad labels: equipment, curriculum development, software development and teacher training. In practice only the first two, the "equipment" and the "curriculum" approaches, are mentioned hereafter, as no country policy can at the moment be said to give a higher priority to one or the other of the last two needs in isolation from the others. Some of the policies consider that governments have a main responsibility in the equipping of educational establishments (either directly, by providing the hardware, or indirectly, through mechanisms of financial support targeted at purchase), or in providing financial and logistic support for curriculum development. Fewer policies target governmental involvement to the production and/or diffusion of software or at least to the coordination of its production/diffusion on a national basis. Yet fewer policies, although recognising it as an important issue, have devoted the bulk of the public resources available to the development of teacher training provisions. Each one of the above differences can be expected to have consequences on the education provided as well as on the evolution of the institution itself, at least in the short and medium range.

c) The "equipment" approach

A smaller number of Member countries are giving priority to investments in equipment, often adopting the top-to-bottom implementation pattern of the "vocational" approach. The "market" aspect of the educational response remains in these cases predominant, at least for the time being. Iceland has given priority to its secondary education to implement a policy of equipment of one or more microcomputers per school. Policy efforts in this country bear also on teacher training and curriculum development (computer studies and computer literacy) but little has been done as yet to develop the "software" counterpart of the policies. The situation is currently evolving towards a more "comprehensive" approach with the development by the Ministry of Education of the new curriculum in computer education for compulsory education and the relevant subsequent development software production by the National Centre for Educational Material.

New Zealand is currently concentrating resources on its secondary level, which by June 1982 had 80 per cent of its schools equipped with microcomputers, purchased mostly through school funds. Some of the Australian states (e.g. Queensland) have also given prominence to equipment concerns with a two-tier policy on initial acquisition and subsequent on-going support and advice, provided, once more, that the purchases reflect central recommendations.

Such a "market" aspect is particularly strong in countries where educational policies have been linked explicitly to national policies of industrial development. Here the equipment for which governments take financial or administrative responsibility is usually produced nationally. Countries where technologies other than microcomputer technology (usually telecommunication technologies) are the object of public investments in education are those where these other technological sectors have been given high national priority in industrial development. To the extent that the latter usually lean on weak pedagogical grounds, these links raise important issues for the possible impact of the technologies thus selected on the former.

The concern with the national electronic industry is explicit in the recommendations, if not in the policies, put forward in yet other countries. In Australia, the 1982 Conference of Directors-General on "Computing and Information Processing in Australian Schools" stated that educational policies eventually developed in the country should support Australian high technology industry through the purchase of local hardware and software products. The Spanish education authorities have defined the characteristics of hardware to be used in schools in co-ordination with the Ministry of Industry and Energy in order to stimulate the national electronic industry. The Swedish development plan for secondary education – a two-year project in five communities – hopes explicitly that the project will "give Swedish enterprises and industry a better chance of competing in the school computer market".

The policy designed to serve the purposes reflects other preoccupations as well. The concern with the national electronic industry is reflected also in the French equipment policy: over FF 2 billion have been allocated over a five-year period (1980-85), to equip universities and schools with nationally-produced hardware. In 1985, an additional FF 1 600 million is being spent on such hardware in the context of the "Informatics for All" plan. Together with the educational policies a national equipment policy has been developed by the United Kingdom Department of Industry offering financial assistance to schools purchasing hardware of national brands.

d) The "curriculum" approach

Fewer are the countries where purely educational concerns top the list of policy priorities. When this happens, the issue most often addressed is curriculum development. Other educational subjects such as teacher training or software tend, in these cases, to remain peripheral to the core of policy and investment considerations.

In these countries the trend is to develop the curriculum on one or more educational lines or in one or more specific years within a given level. Among the Canadian provinces, for example, Quebec is investing in curriculum development for the professional schools, Manitoba has a plan for secondary education in general, while Alberta is focusing on the curriculum starting with Year 4. In Denmark, informatics is being introduced experimentally in the science curriculum, as an option in Grades 8 and 9 and a compulsory subject in Grades 5 and 7. In all these countries there are national plans to bring informatics into technical education.

In Sweden a major curricular – and equipment – innovation has been launched in upper secondary education, providing the same opportunities in the vocational and the academic streams. The Government has allocated approximately SKr 4 million a year, since 1982, for this purpose. The National Board of Education has now proposed SKr 15 million a year starting in 1985/86 for four years. In 1984 the central administration together with the municipal authorities also provided the 9-year compulsory schools with grants of SKr 60 million, i.e. SKr 60 000 for each compulsory school during a three-year period. In Switzerland, there is a national experimental project on the introduction of informatics in the last year of upper secondary education. In Spain, following a reform of compulsory education in 1981-83, informatics has been included in the 8th year of schooling.

Among the curricular recommendations being formulated, the Norwegian Minister of Education has recently pledged that computer science will be available to all pupils, while in Ireland there are specific proposals that informatics should be introduced as computer literacy at junior cycle, computer studies at senior cycle, vocationally oriented courses at senior cycle and briefing courses for seniors not participating in these full time.

Policies for Higher Education

Higher education is the sector with the longest acquaintance with information technology which has been introduced locally and gradually since its birth, according to needs and resources. In most places the recipient attitude has remained virtually unchanged, with the result that the new wave of information technology is finding its way into colleges and universities as pragmatically and autonomously as before, following market demands and availability of resources

According to Pamela Christoffel, national situations *vis-a-vis* higher education fall into three broad categories, reflecting the degree of central planning exercised by governments. At one end, one finds few countries such as France, the United Kingdom and the Netherlands, where, under the impact of economic and manpower pressures, some national policies have been developed that define a role for higher education with respect to their own "technological" development as well as for the development of informatics in the whole education system. In contrast, there has been little national planning regarding higher education and NIT in countries such as Germany, the United States and Canada. Clearly this is in large part due to the federal structure of these countries and the traditionally small role played by their national governments in the development and functioning of their higher education systems. In the United States, for example, the federal government has done virtually no planning for implementation of the NIT into the higher education sector (Shain, 1982). Some planning activities have been undertaken at the State level, through the State Higher Education Executive Offices in particular states. But in most cases planning has been left to individual colleges and universities, with major initiatives also coming from business and industry.

National planning activities in other OECD countries, notably Japan, Ireland, Finland, Belgium and others, fall somewhere in between in range of effort. The impetus in these countries is usually a mixture of forces – economic, manpower needs, desires for regional development and, to a limited extent, plans to improve the education system as a whole. Most have developed at least some plans or established national committees and advisory groups to consider the problem and make recommendations to their governments for future development.

In Japan, for example, a Ministry of Education, Science and Culture *(Monbu-Sho)* advisory committee has recently reported on the merits of information and communication technologies for education, information network systems and the problem of media literacy, including computer literacy. Several study and working groups have been appointed by the Finnish Ministry of Education. One has been examining the potential of Computer-Assisted Instruction in higher education. Another considered the use of computers in university-level education. The Ministry has also prepared a plan concerning the development of automated data-processing (ADP) training in higher education. In Ireland, the Higher Education Authority's Advisory Group on Computer Services has recommended the formulation of a five-year plan for computer development and the establishment of integrated systems and networking between colleges.

In some cases the planning efforts have been followed by actual funding for equipment or programmes. As would be expected, this has generally occurred in Member countries with strong policy development efforts. In the United Kingdom, where the higher education system is generally decentralised, planning work has been going on for some years already. At the end of 1982 the Government announced a £100 million three-year programme for boosting information technology. This called for an additional intake of 2 000 students over the subsequent year in universities, polytechnics and other colleges, building up to over 5 000 in 1985-86. It also included a significant increase in provision in non-advanced further education, and a large new programme of research grants and fellowships. Sixteen polytechnics and colleges were chosen for a £2 million funding programme for information technology courses (Department of Education and Science, 1984). In France, FF 140 million were budgeted in 1983 for university courses, and efforts are currently underway to increase the numbers of students earning diplomas in informatics. Among other higher education projects, fifteen university centres are being established to train teachers.

The existence of planning efforts in these countries should not, however, be taken to indicate the necessary existence of a chronologically ordered series of developments in higher education, such as planning followed in time by provision of monies for implementation. In reality, planning is often carried out at the same time as individual (sometimes uncoordinated) projects are being funded. Few governments have been able to complete comprehensive planning before acquiescing to demands for funding of particular projects or equipment purchases at individual institutions. The result is somewhat haphazard, with planners in some cases trying to rationalise programmes already ongoing. Additionally, it is important to note that the aggregated amounts of declared investments can at times correspond to a highly differentiated – and often uneven – allocation of resources across a number of possible "technological" objectives. A telling example is the French case, where the vast majority of the "technological" investment was aimed at improving computing centres, with only a minute share going to CAI or computer literacy.

Still, renewed efforts to introduce information technology in higher education through national planning have been made in many OECD countries, particularly in Europe, as governments move to catch up with events. As with schools, they are being pressured into action by industrial and marketing considerations, fearing that rapidly-developing technology, bringing new business and new jobs, may pass them by and settle in more competitive countries that have been willing to plan and invest well in time. Indeed the broader problem of economic development in this period of high technology growth is the real spur to government action in colleges and universities. Even countries with no significant national programmes have made a choice. As one expert has pointed out, "Deliberate absence of policy is itself a policy" (Cerych, 1982).

PRAGMATISM, FLEXIBILITY AND UNCERTAINTY

The context defined, and note having been taken piecemeal of countries' reactions to the recent surge of information technology, the time comes to look for the extent to which national policies really are addressing component issues. Our first comment is, not surprisingly, those policies seem to respond instrumentally and pragmatically to the "web of influences" from the context. No doubt, policy priorities have been established first and foremost to respond to the needs most pressing, those of the economy. Whenever they have been formulated, equipment policies define education as an additional market for nationally produced hardware. In most countries vocational concerns have taken precedence over and absorbed more resources than general educational lines, in both schools and universities.

Besides occasional and general declarations on the social and personal importance of achieving more than literacy on the technology, few of the other concerns related to culture and broad social preoccupations have taken a prominent place in policy formulations, although they are sometimes at the core of the programmes actually implemented. More striking is the stance taken by policies with respect to time. While most policy texts give ample space to considerations on the "revolutionary" and "far-reaching" implications of technology for man's life, very few acknowledge the fact that grand designs are likely to need heavy commitments of long duration, and equally durable investments and efforts.

Usually, national policies have been formulated as short term, with a maximum time perspective of five years. At times this corresponds to explicit policy strategies. In some countries, central authorities act as supporters and initiators with a view to handing over their commitments and responsibilities to local authorities after an initial launching period. In other countries, the short-term policy formulations correspond to a two-phase design: a first period of controlled experimentation followed by a longer phase of large-scale diffusion into main stream education, which might or might not involve a shift of roles and responsibilities between central and peripheral authorities.

In yet other countries, the short term perspectives of the policy are the ones usually adopted in similar cases, given the uncertainty and the difficulties of the task at hand. In these instances, the policies are marked as "first instalments", with an explicit commitment by the education authorities to review the situation at the end of the period although with no indications as to the lifetime expected for the more "mature" policy decisions. Obviously, these different approaches to time differentiate policies in their degree of rigidity and flexibility as generators of answers to the questions raised for education by the impact of the NIT on all sectors of society. Such emphasis on uncertainty as a basis for policy is a major and continuing issue.

Finally, also striking, is the attitude of policy towards one of the challenges of the technology to education: that to its own structure and organisation. By and large this issue is not addressed. So far, all policies have been built on the tacit assumption that education will not change face and that the introduction of the new information technology can be planned without altering the structure of the system. Policies therefore are formulated in terms of familiar distinctions: primary vs. secondary, schools vs. colleges and universities, general vs. vocational streams.

Yet, when one turns from policy towards field developments, one is struck by the variety of approaches actually adopted by the multitude of educational programmes and provisions that have come into being over the last few years. Among these the permanence in education in its present form is by no means always assumed and sometimes, even, the technologies are being exploited to experiment with different educational formulae, different forms of financing and of institutional partnership, of allocations of roles and responsibilities across different agencies, public and private, educational and not. The remainder of this report will analyse this process and the many ways in which the system is using the resources available to respond or to resist, to adopt and to adapt.

Chapter II

STRATEGIES OF IMPLEMENTATION

The national policies we have just been considering are responses of governments to the challenge of the new information technology to education. Governments, however, have not been the only, nor indeed the first, of the agencies to have so responded. In most Member countries there has been a great deal of "grass-root" activity initiated by a wide variety of bodies – formal and informal, public and private – in response to what were perceived (rightly or wrongly) to be the merits of the technology for education and the new learning needs it entailed. The objective of this chapter is to examine these endeavours, the support or resistance they have experienced in the field, and to see how they compare with and, possibly, influence the performance of national policies.

NON-SCHOOL STRATEGIES IN THE EDUCATIONAL RESPONSE

Most OECD countries can offer examples of important educational responses to the challenge of NIT originating in places outside the formal education sector. These are very diverse but they have two things in common: explicit educational objectives and the fact that they are neither school-based nor school-related.

Although the relative weight of these programmes and approaches is difficult to assess, a number of them seem to be comparable in their objectives, investments and results, to components in a national system. At all events the relationship between what is done in and for the formal education sector and what is being offered elsewhere is clearly a matter of importance to national planners, especially at present when relatively little is known about it.

Lariccia and Megarry, in their report for the Conference, are helpful here. Their analysis of "parallel" developments in a few OECD countries, for instance, shows that the information technology at the centre of most of such programmes reproduces the same narrow selection (computers and, especially, microcomputers) found in most formal education systems. Mixed technological configurations such as computers and telecommunications or audiovisual devices are as rare in the "open" educational market as they are in classrooms.

Their analysis also touches on the targeting of the "parallel" programmes. Contrary to what happens in formal education, most of these programmes aim at an aggregated and undifferentiated audience, the greater part of which is assumed to be unfamiliar with the technology. The few cases that differentiate the public do so mostly by age, principally addressing the young – mostly the young with problems.

Programmes for the General Public

There are several examples of countries adopting the same kind of approach. One of the better known British examples is the BBC Computer Literacy Project, launched in 1982 by the Continuing Education Department of the British Broadcasting Corporation. It was a complex project on a vast scale with a target audience of millions, if not tens of millions. The main element of the first phase was a series of ten television programmes, the commissioning of a microcomputer from a British manufacturer, a self-study course devised by the National Extension College (NEC) and supported by tutors and study groups operating through local centres, and the Computer Referral Service which puts members of the public in touch with over 1 000 local sources of help. General support and advice was given by the government's Microelectronics Education Programme whose Regional Information Centres were involved from the beginning.

The Project's main aim was to demystify computers by building understanding through practical experience. It was realised through a complex web of collaboration with organisations of different kinds: thus the BBC (a state-owned corporation) enlisted a private computer-manufacturing enterprise, a non-profit-making trust company (NEC), an independent educational charity (Broadcasting Support Services) and a government-funded agency (MEP).

The first series of ten TV programmes (*The Computer Programme*, first transmitted in January 1982) provided a general introduction to the hardware, software and applications, with simple illustrations of BASIC programming built into each programme. About 1 million people watched each programme and about 7 million saw some part of the series first time around. The follow-up series (*Making the Most of the Micro*) was aimed at "users or potential owners" of microcomputers and also at "a general audience of the technically curious". It was first transmitted in January 1983 and quickly built up a total weekly audience of around 3 million viewers. It was widely used in recorded form by schools and colleges. The second series assumed some familiarity among viewers and looked in more detail at topics like string handling, graphics, data bases, control and business applications. Subsequent series have included *Computers in Control* and *The Electronic Office*.

Also based on partnership among a variety of national agencies is the French project launched in summer 1983 by the *Centre Mondial Informatique* under the title "Holidays for the Future". This was the first stage of a large-scale action programme called *X2000* which aims to set up 1 000 regional permanent resource centres for NIT. The initial grant was for FF 10 million, supplemented locally by the regional authorities. Almost 400 centres with more than 2 000 microcomputers of French manufacture were open on average for the two months of holidays, to generate interest in the new information technologies and to give a wide variety of people the opportunity to handle a computer. Admission was free and enrolment was not generally necessary. Methods of organisation were left open to each centre.

The centres were visited by almost 200 000 people, about 40 per cent from 12 to 18 years old. Interestingly, the project was more successful in the most disadvantaged areas. The computers loaned to the centres were to remain there for the year to be available for social and occupational integration activities initiated by the Ministries of Vocational Training, Leisure, and Youth-and-Sports. A noteworthy feature of this project is its multiple use of the same structure and facilities for different purposes, including local government educational projects. It also illustrates collaboration between the public sector and private enterprise. Ultimately the main goal achieved by such a large-scale project is the general raising of awareness. Providing the whole population with easy access to such facilities is considered by the French authorities to be a major step towards equalising opportunities.

Equally popular, although with a more socially restricted target group, is the project launched by a private French holiday chain, established internationally. Introduced in summer 1981 in one of its holiday "villages", its "computer centre" notion spread quickly to others around the world. After the first three years of operation, these centres have been estimated to have attracted more than 100 000 visitors. They offer games, information services, self-study courses and applications software so that participants can familiarise themselves, play, and learn with microcomputers and about information technology.

These holidays are expensive and this is reflected in the socio-economic status of the guests – professional, managerial and business people, self-selected in response to a commercial initiative. The camps have inevitably attracted a flood of offers from manufacturers to supply equipment. In effect, they present a huge shop window to guests with considerable purchasing power – both as individuals and through influence on their employers.

More democratic is the setting-up in some other countries of large, permanent exhibition centres, designed to make all citizens familiar with the technology and with some of the related issues. A typical example is the Dutch "Evoluon" in Amsterdam. This is a permanent exhibition of 4 700 square metres which explains familiar technological objects and displays the role of science in the ever-changing world. It was opened in 1966, and is financed by a multinational electrical company. Annual attendance is 450 000 and there are special facilities for schools. Its scope embraces the significance of technology for industry and society, the important things for life and health, comfort in and around the house, and issues related to recreation, education and communication. Special presentations focus on computer technology, history and applications. The central question which the Evoluon tries to answer for each visitor is "what does technology do for me?"

Attempts to reach out to the larger public are also instanced in many countries by exhibitions and fairs offering "instant" computer literacy courses. According to Lariccia and Megarry, these usually have little educational value. Though many of the visitors genuinely want to understand the potential value of NIT in their private and working lives, there is seldom any means of relating their needs to what is on show. All too often they leave baffled and confused.

An effort to overcome this problem is a programme staged by an Italian magazine at some of the country's major fairs. Its two-hour introductory sessions are attended by roughly one per cent of the visitors. The limit is often imposed by lack of space and teachers, not by lack of demand. The overt theme of these sessions is an understanding of the potential value of NIT in visitors' private and working lives. Each participant has a machine on his or her desk and is able to continue playing around with it after the introductory lecture. A helpful booklet prepared by the magazine accompanies the presentation. We are told that this exhibition attracts hundreds of thousands of visitors every year, so it should suggest an important method for introducing a lay public to information technology.

Programmes for the Young

One way of familiarising the young with information technology is to introduce appropriate programmes in places already devoted to their "informal" education. An often-cited example is the Capitol's Children's Museum in Washington, where a section on computers and communications, rich in good examples, presents the new technology in a way that emphasizes continuity with other eras and civilisations. The museum is a private institution, supported largely by the private sector. It publishes a good magazine and has a research group in computing which has produced important educational packages. Equipment donated by a United States computer manufacturer enables instant practical courses to be run for visitors who may book in advance from anywhere in the United States. The museum has been designed with a view to the long-term future. Local networks (for data, voice and images) are gradually becoming operational. A satellite station allows broadcasting and reception of other types of information. A powerful computer assists the advance provision for groups of visitors and enables the printing of "instant books" for them to take away.

Another way to reunite young people and technology, increasingly popular in a number of countries, is through residential summer camps. A good example is the INTER-ACTION community computer camps in the United Kingdom. The INTER-ACTION Trust Limited is a registered company and charity involved in a great variety of techniques for community self-help. Its strategy is to inject resources and ideas, to provide support during implementation, and – once a nationwide network of autonomous local groups is established – to encourage them to form a federation to sustain the work. The first series of Community Computer Camps was established in London during 1982. Six one-week non-residential camps for eleven- to sixteen-year-olds were offered during the summer holidays. Of these first 224 students, 42 per cent were from inner London, and 23 per cent were girls. Two-thirds of the students had no previous experience of programming, but most completed successful projects before they left and 64 per cent wanted to join a computer club to develop their interest.

Crucial to the success of the INTER-ACTION Camps is their high ratios of tutors and of computers to students. The fact that these can be combined with low fees (from £20 per week down to £5 per week) is a measure of the organisation's success in attracting subsidy, sponsorship and donations in kind. They also have a flexible approach to recruiting computer studies students as tutors, to using existing spaces made available by local authorities, and to rewarding generous computer manufacturers by publicising their contribution widely.

INTER-ACTION aims to establish a nationwide network of 500 camps by the end of 1985 using the same basic model. Its interest lies less in its initial quantitative intake, obviously too small to be of any general significance, than in the institutional and organisational model it proposes. It has demonstrated its ability to change the usual pattern of under-participation by females, by ethnic-minority students and by those from inner-city areas by marketing the camps specifically towards these target groups. The motivation behind Community Computer Camps is threefold: avoiding waste, redressing under-privilege and building community self-help. The approach is well documented in a practical handbook for those wishing to establish Community Computer Camps.

Larger and more diversified is the family of parallel programmes for special groups of young people, among them the young unemployed, the disabled and the "potentially antisocial". Examples of the latter can be found in France – for instance the special integration course run by the Abbaye Association, a non-profit-making association involved in training likely dropouts and helping to prevent delinquency. In 1982-83, on the assumption that computers help to individualise teaching, that they provide a valuable new communication medium and that they are a natural vehicle for technical training, this association decided to include computer training in its educational activities aimed at promoting social integration, encouraging success and providing some technical training.

Member countries also offer some imaginative examples of computer technology being applied to alleviate handicap. Besides the familiar examples of computers used as prothesis to compensate for some physical disability, there is a growing body of experience where Computer-Based Learning environments such as LOGO have been used successfully to treat some psychological problems that could lead to severe learning disabilities. Another group of young people for whom a good number of computer-based courses have been designed is the unemployed. These programmes often combine two popular working hypotheses: that computers hold a therapeutic potential towards inadequate acquisition of skills and that computer-related skills increase one's value on the labour market.

These are the objectives, explicit and implicit, of the UK-based Information Technology Centres. Announced in 1981, a network of 175 such centres was expected to be complete by the end of 1984 as a permanent contribution to education and training in information technology. Interestingly, neither the Department of Education and Science nor the Scottish Education Department were involved in this initiative; the Centres were a joint creation of the, then, Department of Industry and the Manpower Services Commission. Their purpose is twofold: to give unemployed young people (especially those under 18) vocational experience and training in NIT that could facilitate their search for employment; and to foster co-operation with local businesses developing and producing marketable products and services using NIT.

Although the Centres vary in character, the normal pattern is for sponsoring bodies (local authorities, technology-based enterprises and others) to get them established as limited liability companies. They normally have 30-40 trainees, attending for between six and twelve months at a time. Trainees are encouraged to seek jobs or return to full-time education and, of course, they may leave for these reasons. Curriculum guidelines suggest four main courses: electronics, computing, the electronic office and some production activity. Induction training allows trainees to sample these areas before deciding where to specialise. Some assistance is given in developing life and social skills, and there is personal guidance and counselling. On departure, all trainees receive a Leaver's Certificate detailing their work experience, training and further education.

The ethos and atmosphere of a typical Centre resembles a place of work rather than an educational institution. Although demand often exceeds the supply of places, selection is unlikely to depend on academic qualification and school reports. Some Centres use their full-time trainees as tutors for computer literacy courses mounted for participants in the Youth Training SchemeYTS, the largest scheme for unemployed youth in the country). Such participation is revenue-earning, since the MSC pays the Centres to host these courses. It is also a good educational and social challenge for the full-time trainees to have to pass on their newly-acquired skills and competence to the YTS trainees. In effect, the Centres' supervisors operate at one remove, monitoring the quality of the training provided by the full-time trainees.

The idea of having the young teaching the young is at the heart of another programme for the unemployed, known in France under the name of "Soldiers in Informatics". This project was mounted by the *Centre Mondial Informatique* in connection with the "Conférence des grandes écoles". A substantial number of young people serving in the French army, with recent degrees in informatics from the most prestigious *grandes écoles* have been allowed to do their national service training unemployed people in computer-related skills. This training is done rigorously, under the direction of a team of specialised teachers, and the soldiers are given extra pay. The assumption here appears to be that preparing the rising generation for a world of technology is comparable with training them for the nation's defence.

Telecommunication-based Projects

Educational programmes are also among the wares offered by a small – but growing – number of electronic service networks. In an area where private initiatives are now multiplying apace, it is worth recalling some national programmes and experiments, now historical, that led the way.

The British Prestel was launched in 1978 as the world's first public viewdata (interactive videotex) service. Although the potential of such a system was seen to be immense from the beginning, its actual uptake by paying customers has been disappointingly slow, especially among domestic consumers. An important reason for this is, of course, the cost. With Prestel one pays for telephone connection time, for computer time and also for individual frames. The total varies according to the time of day, and the distance from the Prestel computers and the decisions made by Information Providers: excluding frame charges, a subscriber might pay anywhere from £0.66 per hour to £15.90 per hour. Although Prestel's initial policy was to provide a general information service, and to act as a "common carrier", there has been a marked trend towards provision of specialised and private information services, especially for business groups.

With its over 200 000 pages of information the Prestel data base contains a vast amount of information and represents a major educational resource both in itself and for the lesson it illustrates in information handling. It has a potential role in the teaching of information technology, social studies, business studies and economics. A major project by the Council for Educational Technology has investigated its scope both as an educational resource and as a mechanism for delivering telesoftware. CET found great enthusiasm for local viewdata software systems, which proved both valuable and cost-effective, not only for teaching about Prestel, but also as a project in collaborative knowledge building for teachers and pupils, with applications ranging from electronic magazines to the design of crisis simulations.

More strictly geared to home use was an experiment run in France: the "Vélizy experiment", by now a "historical" example, which was at the origin of the telecommunication service currently available nationwide. In this experiment 2 500 families in the Paris area were provided with Minitel terminals giving them free access to videotex services, covering passive or one-way communication (teletext) and interactive services (viewdata). Passive services provided news, travel and other information services, whereas the interactive services allowed the user to send messages, order goods, book tickets and participate in Computer-Assisted Learning. The *Direction Générale des Télécommunications (DGT)* sponsored research into the personal characteristics of different levels of user. At the outset, all users were given two educational programs and both an electronic and a printed index to the information available.

"Heavy users" formed 30 per cent of the total, learned to operate the terminal inside a fortnight, and used a variety of services including the interactive facilities; some called the system every day. By contrast, 25 per cent of the total group never used the terminal at all and wanted to return it. The remaining 45 per cent of "very infrequent" to "medium frequency" users made little use of the interactive facilities and used the system only once or twice a month.

The participation pattern was clearly related to age and gender. Pensioners were usually very infrequent users while youngsters were heavy consumers of games irrespective of their socio-economic status. Females were generally under-represented, but among heavy users they came nearer to equal participation. Socio-economic status was also a determinant, with professional people and white-collar workers dominating the higher use categories, and blue-collar workers being the most numerous among the very infrequent or non-users. One of the main objections was the difficulty users had in operating the terminal. Another was the lack of relevance of the information provided by DGT – some of the non-users, for example, were business and professional people who wanted more specialised information services. Interestingly, some non-users did not return the equipment: its mere possession seemed to confer social status.

STRATEGIES OF POLICY IMPLEMENTATION

So far, we have detailed the interests, pressures and concerns at the back of current policy approaches and have indicated another set of influences that may come to bear from the growing number of provisions developing in the non-formal and non-institutional educational market. Either set of factors is likely to play a role on the road between policy guidelines and their implementation.

Given the variety of "formal" policy approaches and of the parallel output of the "open" market, it is no surprise to find that strategies of implementation differ widely. To understand the nature and consequences of these dissimilarities, it is necessary to consider them within a common framework where the appropriateness of a policy approach can most critically be put to test: this embraces equipment, curriculum (and the sister front of software), teachers and pupils.

Developments in Primary and Secondary Education

a) Equipment strategies

Strategies for equipment cannot but amplify the variations in policy formulations as they have to equate these with the equally large variations pertaining in the formal system, in schools and elsewhere. Here, in almost every country, information technology has found its way into the system prior to and irrespective of formal policy interventions. Forecasting the success of "official" policies and implementation strategies depends to an important extent, therefore, on the possibility of assessing whether the "official" and the "spontaneous" developments will reinforce or oppose one another. Few data are available at present to permit these kinds of considerations. A most important first element of information needed concerns the actual technology entering education.

Most educational policy formulations specify information technology rather narrowly and, to an extent, imprecisely: the texts often identify the hardware target simply as "computers". This reproduces the selection operated over recent years by individual schools when responding to the newly developing markets of electronics. While more objective professional and technical criteria can of course be discerned in current policy formulations, it remains that most of the efforts introducing the NIT aim at equipping schools almost exclusively with the new generations of computers: the mini- and, especially, the microcomputer.

Initiatives taken to introduce other technologies alongside or as substitutes for the previous ones, remain essentially peripheral to the current efforts of governments, schools or education authorities. Among these some are worth mentioning as they may come to play a more important part in education's role in the new "technological" world. Examples are: the use of databanks as an educational tool in both primary and secondary education (Australia); the use of videotex optical fibres and videodisks (experimented in France, Canada and the United Kingdom); the link-ups to telematic networks (Canada and Australia, where the educational use of satellites is also under consideration).

Nevertheless, as already mentioned, the technical term "new information technologies" is translated almost universally in educational policies as "micro and minicomputers". The singleminded governmental approach to these members of the information technology family goes beyond a simple question of narrow definition. They are most usually the sole devices called in by central education authorities when developing strategies to equip their schools. Other technologies such as telematic networks or audiovisual systems are rarely considered. This discrimination materialises in most countries either by direct purchase and allocation of specific hardware or by special purchasing grants made to schools and local education authorities (provided the Ministry's purchasing recommendations are followed). The central involvement in the equipping of schools with microcomputers seems to be taking place in centralised as well as decentralised education systems. For instance one finds a rather similar equipment policy approach in the United Kingdom where local educational autonomy is profoundly established and in France, where the Paris-based Education Ministry has been ruling the national schools network without interruption since Napoleonic times.

A first consequence of such equipment policies is to narrow the variety of microcomputers introduced in the schools to only a few of those available on the market. In addition to being narrow, such choice of microcomputers is often restricted further to those produced nationally. This increases even further the likelihood of differences between countries, the future consequences of which we shall discuss later.

A second consequence of central intromission in equipment strategies is the establishment of priorities between the two policy objectives of equity and efficiency. Although little is known as yet as to the specific impact of microcomputers on learning processes, it is obvious that it must depend, perhaps critically, on the time the learner spends with the machine. The number of microcomputers per school, or even better, per pupil in a school, is therefore an important parameter to consider when allocating equipment. The efficiency principle would require the allocation of resources on a progressive geographical basis, so that each successive school served has *enough* equipment to offer to its pupils. So, even if an efficient equipment policy is justified on educational grounds, its political legitimacy in the current economic situation may well be disallowed. This is perhaps why most of the OECD countries who have developed a policy on equipment have preferred equity to efficiency whenever there was possibility of a conflict. The only explicit exception appears to be France where the equipment policy is formally aimed at an initial target for each school, the equity puzzle being solved by a careful selection of schools within each region.

As to the relationship between official and independent coverage, there is at least one aspect in which they concur: relative neglect of the primary education sector. In most of the OECD countries for which the information is available, it sees much less of NIT than the higher school levels do. With the exception of the United Kingdom (England), no country reports the presence of NIT in *all* primary schools. The current figures are around a ratio of less than 5 per cent of schools being equipped, although some federal countries such as the United States, Canada and Australia report equipment ratios of up to 45 per cent depending on the state/province. Note that for the secondary level figures up to 80 per cent are indeed very frequent. While these official figures embrace the effects of "official" and "spontaneous" initiatives, the fact that the pattern does not change when the schools are reported to have been the only purchasers (own funds or funds raised by teachers and parents) confirms that official and parallel agents set their targets by educational level.

There are two independent forces within the formal system that may or may not work in accordance with the official line. For example, in most of the countries well advanced in the introduction of NIT in education, more money for hardware has come out of the normal equipment budgets of schools and local education bodies than from the special central funds that can be drawn on locally to implement some official "technological" policy through a mixed funding formula.

In Scotland, where the combination of the Scottish Microelectronics Education Programme and the Department of Industry equipment programme was intended to accelerate the introduction of the NIT in schools, the typical purchasing pattern for equipment by late 1982 was: 10 per cent SMEP, 15 per cent DoI, 3 per cent other research projects, 72 per cent schools' own funds.

The existence of such local and parallel interest and expertise prior to and possibly independent of larger-scale educational projects is something the central planners need to take into account; otherwise they might find variations that run counter to their desires – for instance in the hardware already present in the schools, the use it has been put to in the curriculum, the kind of expertise (or idiosyncrasies) developed by the staff and the pupils involved and their readiness to adapt or adopt specifications.

b) Software strategies

That the purchase of computer hardware makes no sense unless accompanied by a parallel investment in software might sound a platitude – and indeed it is.

Yet few Member countries have shown evidence of this in their development plans or policies. Notable exceptions to this are France, the United Kingdom and some of the Canadian provinces and the Australian states. "White Papers" on technology and education released in 1984 by Australia, the Netherlands, Norway and Sweden do in fact recommend national policy developments of a more "comprehensive" nature; but until they are realised, local expertise and financing will remain the main source of initiative for building up the body of software needed to translate the word "equipment" into "learning activities".

Whatever its origin (centrally or locally produced) educational software remains a rare commodity in the educational world. The little of it that enters the schools seems to be essentially endogenous, being produced, for better or worse, by teachers and/or by computer experts within ministries of education or local education authorities. Apart from this (and with a few exceptions such as the United States) the current market for schools has been only marginally penetrated by other traditional sources of educational materials such as producers in the private sector or the universities.

Teachers seem to have produced, usually without central guidance, most of the software used in the schools of Denmark, Finland and Japan. Experts from the computing centres of ministries of education, working alone or in co-operation with schools' teachers, have authored most of the educational software in France (***Institut national de Recherche pédagogique***), the United Kingdom (the central and regional structures set up within the Microelectronic Education Programme and the Scottish Microelectronic Education Programme), Sweden (the expert teachers involved in the PRODIS project), most of the Australian states (the computing branch of the state's education department) and Belgium. The universities have so far played only a minor role in this field. France, Japan and Belgium, together with some of the U.S. states and the Netherlands seem to be the only reported cases so far.

The fact that most of this software is being produced within the education system does not seem to guarantee anywhere that it has a quality for education. Most educationalists do not hesitate to qualify the quality of existing software with the euphemism "very varied", and one may well anticipate that, in the absence of an official policy on software and with the uncontrolled multiplication of local piecemeal production, the situation will worsen. It is therefore important to draw attention to such efforts as are being made to find at least a preliminary solution to the problem.

The strategies being developed to control the quality of educational software are of two kinds that often coexist and reinforce one another. The first family is of the "preventive" kind. It ensures quality in one of two ways: by issuing guidelines with specifications on programming and by controlling (as far as is possible) the software's authorship. In the United Kingdom, for instance, booklets have been issued with guidelines for teachers wishing to program. The Australian state of Victoria has also adopted this approach.

The second group of "preventive" strategies approaches the quality objective in, again, one of two ways. At times the authorship of quality is ensured by having the educational software produced within institutional bodies by especially hired – and qualified – personnel. In other cases, an authorship of quality is ensured at a more grass-root level by making software production an important part of teacher training programmes. Examples of the first kind are more frequent. They include all the cases of "expert" authorship mentioned in the previous paragraphs, the software being produced mostly within some national educational institution or another. The second approach – through teacher training – is so far less common. The best example comes from France, with its carefully-designed two-tier programme of training for school teaching staff.

The second family of strategies to control the quality of the software may be termed "remedial". They do not attempt to influence its production, but try to monitor and control the stream of software that actually penetrates into the schools. The means employed is for qualified, official bodies to issue lists of approved ("good quality") material. This is the case in British Columbia and Alberta and the United Kingdom. Since 1983, Finland has also adopted this approach, and reinforced it by a parallel initiative: special grants to schools when they buy software on the National Board of Education's approved list.

A "quality label" on the product is certainly a helpful guide to the buyer, but it is not in itself sufficient to guarantee that it will be the most useful. To be that, the software needs not only to be good but also to fit in with the equipment and the curriculum already installed in the school. In short, it must be "transportable". The issue of "transportability" is exceedingly complex. Le Corre and Schwartz define it as (trans)portability between types of equipment, across computer languages, across disciplines or between software producers.

With hardware, for example, "portability" indicates compatibility between interfaces. This covers hardware characteristics such as type of keyboard (QWERTY or AZERTY, accents, function keys), type of information medium (size, sector pattern, density), type of screen (number of lines and columns, character definition, colour, graphic functions), type of connection to peripherals (series/parallel, V 24 socket, Peritel socket) and type of central processor.

Portability is possible between microcomputers operating with the same microprocessors but this is not always the case. Moreover, there are currently four different levels of Computer-Assisted Instruction (CAI) systems in use: videotex terminals, personal microcomputers with viewer, small printer and cassette recorder, microcomputers with larger peripherals and minicomputers or mainframe computers.

The lack of uniformity between processors and peripherals creates difficult problems of portability and compatibility. The situation becomes even more complicated if one wishes to run a simplified version of the courseware on configurations less sophisticated than the high-level ones for which it was originally written, comprising the microcomputers and the terminals just listed. The functions usable for the instructional dialogue are insufficient in the case of videotex and of a fairly low order in the case of 8-bit microcomputers, but the situation is changing rapidly and the above four levels could well be reduced to two. Videotex systems are starting to use microcomputers as their "intelligent" terminals and microcomputers purchased for schools now incorporate 16- and even 32-bit processors.

From the user's point of view, the best solution to portability problems will often be microcomputers connectable to more powerful computers so as to have no difficulty in using the latest courseware versions, to be able to make use of ancillary resources (operations requiring substantial computing power, vast arrays of data requiring frequent updating), to be able to consolidate the results of sessions and thereby improve courseware by the fine analysis of these results, and to be able to consult and try out existing courseware packages.

Le Corre and Schwartz also looked into software portability in some detail. Some courseware can only be operated on hardware configurations designed specifically for CAI and are therefore not portable to other configurations. Given its high production costs it is important that quality courseware designed for a wide range of users should be compatible with any of the types of hardware they may have. A further requirement is that the controlling software as well as the courseware follow-up should be portable, which in turn means portability of the relevant software.

The strategies developed to ensure transportability of the software have been *ad hoc* and limited to only some of its aspects. The most commonly selected has been language transportability. The solution has been to adopt a common language either by prescription, as in France (LSE), or *de facto*, as in Denmark and Ireland, where COMAL 80 has rapidly become the most widely used programming language for educational software.

Another way of ensuring software portability is to write the courseware in a computer language used by a large number of authors, such as BASIC or PASCAL. However, there are several versions of these languages, which depend on the type of hardware that supports them. An attempt has been made to standardize some of these languages (e.g. PASCAL USCD, the choice of several states in Australia). But this does represent a considerable advance on the proliferating versions of BASIC (not to mention its graphics and sound extensions).

In some cases, portability can be incorporated at the level of the Operating System, e.g. CP/M or MS/DOS which then become virtual standards for microcomputers. Failing this, translations are made, with varying degrees of success, from one language to another. Run-time hardware interpreters and emulators represent partial solutions more in use. It is anticipated that this rapidly-developing technology will evolve new solutions in the future. In the meantime, rewriting software as necessary is likely to be the solution for those needing it.

A different method is to represent the courseware as data for processing. The data for a CAI lesson may need reformatting, but this is considerably easier than if each lesson were a program requiring translation to a new programming language or conversion to a new computer system (McDonnell Douglas). Another solution is to use a standardized internal representation at computer level. One instance is the DIANE Project in France. Portability is ensured by some 150 standardized capabilities to incorporate the educational content. The internal representation includes no implicit instructions, imposes no teaching strategy and will support any desired extension. It therefore guarantees portability. On the other hand, it makes it harder for the author to express material directly and does not guarantee educational portability, although these weaknesses can be overcome by using special purpose editors or by a language form in which the author can describe his data within a structure in which he is no longer obliged *fully* to describe the usual instructions. Those instructions are specified as part of the teaching strategy freely chosen by the author.

In addition to these specific cases, software transportability is an obvious by-product of other implementation strategies. Any national equipment policy, by restricting the variety of hardware introduced in the schools, ensures software transportability at least at this level. Similarly, solutions to the problem of software "quality" contain elements ensuring other kinds of transportability. The formulation of guidelines for programming or the control of authorship introduce an element of similarity and homogeneity in the software produced which, if not solving the problem altogether, does certainly alleviate it.

The development of strategies to produce software, to control its quality and to ensure its transportability are the first elements in the chain bringing the products from the producers into the schools. To close the circuit, one needs to develop the final link of making the products known and accessible to the users. Yet information and distribution networks, in most OECD countries, are in an extremely primitive state. With the exception of a few countries, such as France, the United Kingdom, some states in the United States and provinces in Canada where a co-ordinated effort is being made to introduce the new information technologies in education, and where the software is distributed by the same agencies that control its production and quality, the ways in which schools get ahold of the available software are at best hazardous. How it moves varies widely between countries. For example: in Japan, by diffusion and exchange between two large teacher associations in industrial and commercial schools; in New Zealand, within and between a number of users' groups and computer education societies; in Western Australia and in Tasmania, within a communication and distribution network set up by the Education Department; in Ireland, through the Computer Education Society.

Here we conclude our examination of that part of the NIT and education story that lies, as it were, between the Ministry of Education and the school's gate. Next to be considered is how national policies and strategies for implementation are making themselves felt in the schools themselves. This we shall do, taking first matters of the curriculum and then the teachers.

c) Curriculum strategies

In the translation of equipment and software strategies into curricular ones the first main differentiation occurs by level of education, between the primary and the successive school years. If the primary schools are the less affluent in equipment, they certainly use it in a simpler and clearer fashion. Across the OECD countries, the primary curriculum uses computers mainly for practice in basic skills and, accessorily, for remedial education. The secondary curriculum, on the other hand, involves the computer in very different ways, with specifications depending in an often unclear fashion on the specific level of schooling considered, the discipline, the school and the country.

While the computer has entered the primary schools essentially as part of "Computer-Assisted Instruction", there are a few countries where its use has been more ambitious. Examples of this kind come from Australia where, in some elementary schools, children are taught a few elements of computer science (usually programming through LOGO). Notions of computer science are also given at this level in the United Kingdom and in Denmark, where experiments in *datalaere* are run in years 5 and 6. Next to computer science, some primary schools have also introduced "computer literacy", mostly but not exclusively as an integrated subject within the mathematics, social sciences and civics curriculum. The actual provisions in this case comprise formulae ranging from a full 30-hour course in years 4, 5 and 6 (as in Alberta) to a more modest integration in other curricular subjects, as is more frequently the case.

The situation in secondary education is rather different. The kinds of provisions introduced within the curriculum are so varied that it is difficult to establish even a superficial taxonomy. Under the label of "computer assisted instruction" the computer, no longer confined to the sciences, has penetrated virtually all curricular areas, although at speeds which vary greatly across countries, schools and levels of education. The curricular status and content of computer science and computer literacy (or appreciation) are equally disparate.

One of the first (and unexpected) elements of inconsistency in this area is the absence, in some countries, of clear-cut boundaries between what are commonly called "computer science" and "computer literacy", which are usually roughly defined as covering technical subjects on computers in the first case and considerations of their social implications in the latter. In Finland, since the 1982 reform, the two fields have simply been merged into one. In England and Wales, the computer science curriculum has "historically" covered subjects such as the uses of computers and their effects on society. Conversely, the "computer literacy" curriculum in Scotland and in the United States often includes elements of programming. In Norway, computer appreciation is available as an integral part of the computer science syllabus, and also (in some schools) as an independent, and compulsory, course.

Equally disparate is the actual organisation of the courses available in the countries, both across and within the national borders. The overall situation can best be described by the laconic response of the United States education authorities to the questionnaire sent by CERI: "the provisions available vary widely in content and length". One can indeed find that to teach computer sciences in Canadian secondary schools takes anywhere between 50 and 100 hours in a year, depending on the school and the province. In Belgium it takes between 294 and 336 hours a year for the specialist students and "only" 84-168 hours for the other vocational education students.

The variations found for courses in "computer literacy" (when a differentiation of labels, if not of content, exists) are of the same order of magnitude. Across the Australian states the curricular time taken up by this subject varies from a lowest five hours a year, in Tasmania, to a highest 126 hours a year in the Capital Territory. In New Zealand the variation is less important ranging between 12 and 30 hours a year for the unit of study offered in Form 4.

The only (modest) trend observed in this area is that the length of the courses seems to increase with the age of the learner. In Western Australia computer science is offered for 1.5 hours a week at Grades 9, 10 and 11, and for more than double that time at Grade 12. In Luxembourg, the time allocation goes from 72 hours a year at Grade 11 to 164 hours a year at Grades 12 and 13. In New Zealand, the corresponding figures are of 80 hours a year in Form 7 to 160 hours a year in Form 6, with this last opportunity offered, it must be said, in few schools only.

Such multiplication and differentiation of the provisions created in the countries in the 1980s has defused the traditional ammunition brought by the supporters of computer science as a separate or an integrated subject to the heated debate of the 1970s. With the exception of a very few countries such as Sweden or Denmark which have taken an explicit policy stand on the question in favour of integration, other national situations are mixed at best. In Finland computer science is taught as a separate discipline in 90 per cent of the schools, but also as an integral part of the mathematics curriculum. The situation in Spain is similar with the option in Grade 8 integrated and that in Grade 12 separate. In New Zealand the shorter course given in Form 7 is part of the mathematics curriculum, while the longer provision offered at Form 6 constitutes a separate subject. In the Australian state of Queensland, computer literacy appears also in the two curricular forms.

In view of all this, it is certainly not surprising that little consensus exists within and across the countries as to whether "computers", in whatever curricular form they come, should be an object of formal examination. Computer science is a subject for the *Abitur* only in a few of the German *Länder*. It is also an option for the *O level* in mathematics in Ireland. In Scotland, computer science is being piloted in 17 schools at the same examination level. In the other countries the situation is varied. At times "computers" are simply absent from the exam syllabus. At other times they are included. In the general education stream, they usually appear as a subject integrated in other established disciplines. In the vocational education certification system, they are dealt with mostly as a separate examination subject.

d) Teacher training strategies

The strategies for implementing training policies for teachers seem to be very similar to those for the software and the curriculum: unclear (an array of provisions with no clear-cut systemisation of objectives, content, duration and educational level is reported from Australia, Canada and England and Wales); unsatisfactory (Japan); or non-existent (only nine out of the 24 OECD countries have reported having any training provisions for teachers with respect to NIT).

Comprehensive national policies specific to teacher training in NIT have come into effect in only two countries: Sweden and France. In Sweden they were introduced with the general reform of teacher training in 1982, involving an initial investment of SKr 3 million. The provisions are mainly in-service and are tied to the curriculum. Teachers from the compulsory cycle receive a three-week course on computer appreciation. Teachers from upper secondary schools are trained for longer (at least five weeks) and study more advanced subjects, such as computer utilisation and programming.

The French government's policy in this matter is an important ingredient in its ambitious plan to introduce the new technologies in education comprehensively. These provisions are made unique in that they differentiate between the various functions teachers have with respect to the NIT, for example, between the software producers and the users, and between the trainers and trainees, the first of whom receive a full year training course (in universities) and the latter only twelve days in a local setting.

A similar conceptual differentiation in teacher training provisions is at the core of the "Standard Curriculum Guide for the Training of the Educational Usage of microcomputers" recently released in Japan. According to this, teachers are to be trained to achieve one of three levels of competence. Those qualifying for the "elementary" level are expected to be able just to use computers. At the "intermediate" level teachers should be able also to write computer programs and evaluate their educational worth. "Advanced" level provisions enable teachers to acquire the additional competence of instructors. Although similar in conceptualisation, the Japanese guidelines differ markedly from practice in France in the matter of timing – the most advanced, and longest, training programme not exceeding a maximum of 48 hours spread over eight days.

As for the other countries, our information at the moment is somewhat sketchy. There seem to be fewer initial than in-service training provisions; few countries offer both. Most often the initial provisions are included in the regular courses for teacher certification – primary school teachers appearing to get slightly favoured treatment.

Surprisingly, the differences in equipment observed everywhere between primary and secondary schools does not translate into corresponding differences in teacher training provisions. Better equipment in the secondary schools does not seem to evoke correspondingly better training provision for their teachers. With the exception of Sweden, already mentioned, and of Belgium, where the length of the training courses in the Dutch-speaking area varies by school level (from a 24-hour course for primary teachers to five to ten days for teachers from state schools and ten to 14 days for the further education sector), other countries seem to have defined both responsibilities and expertise similarly across educational levels, without any visible rationale.

The providers of teacher training are usually the education authorities of the country or the state who also supply the trainers, often specialist staff from the ministries or the schools themselves. In Belgium and France, however, the trainers come from the higher education sector, usually because of their expertise in informatics, not necessarily their experience as educators. In the Northern Territory, Australia, and Ontario, Canada, the trainers come from the private sector – from consultancy agencies or the computer manufacturers themselves.

To summarise what we have been saying, only a low percentage of the countries' teaching forces has so far received any formal training to make use of the equipment newly supplied to the schools. In France, where the investments are largest, by mid-1985, 2 500 teachers had followed the "heavy" training and 45 000 the "light" one. Another 110 000 will be initiated by the end of 1985. In England, 80 000 teachers have so far been trained. In Sweden, the carefully-designed programmes have served 8 000 teachers in two years. Elsewhere the ratio of the teaching force trained does not exceed a few percentage points.

Yet the demand from the teachers is sizeable; their attendance at courses, usually voluntary, shows unmistakably that they are interested to learn, while the number of applications from both levels far exceeds places available. This attitude is mirrored in the teachers' unions who, by and large, are noticeably more positive towards the introduction of computers in the schools than they were fifteen years ago towards audiovisual material.

The need, then, for more and better training for teachers, both initial and in-service, remains as urgent and vital as software production/diffusion and curriculum development.

Developments in Higher Education

The scarcity of specific national policies for higher education has not prevented quite a number of colleges and universities from beginning themselves to introduce the new information technology. According to Bollerslev and Estes, this process normally starts at the budget stage by developments associated with the technology being given high financial priority. Although most of the allocation is spent on hardware, there are often provisions, too, for the conversion of physical facilities and the development of special courses.

While, however, the outcome of these initiatives may have been the addition of new departments, of new courses within departments and, even, new degree programmes, the change itself can only be seen so far as interdepartmental, as distinct from a component of co-ordinated development in the college or university. Some, it is true, have centralised new purchase and planning/decision-making for the NIT technology; but the majority leaves it to individual departments and/or faculty members to develop their own plans. Computer courses are, of course, a standard part of the curriculum in such disciplines as statistics, the physical sciences and engineering. Information technology is also used extensively in American colleges and universities to deliver professional continuing education, for instance in allied health professions, medicine, engineering and high technology, business, education, law and real estate (Lewis, 1983).

The United States also has a number of good examples of the use of NIT other than computers for professional education. One of these is an association of 17 universities in the Dallas/Fort Worth area, the Association for Higher Education of North Texas, which operates the TAGER Television network, the largest close-circuit higher education network in the United States. 85 per cent of its courses are at graduate level for engineering, business and computer science. TAGER has developed a hybrid distribution system using ITFS broadcast, point-to-point microwave, cable, satellite, videocassette and telephone and has a unique organisational structure that shares governing powers between the local communities (two-thirds) and the higher education institutions participating in the programme (one-third). It thus combines complex technology and low-cast video production to serve highly motivated learners in professional fields (Lewis, 1983).

Although still focusing on professional education sectors, some colleges and universities have, more recently, extended their efforts to educational provisions for the non-specialist. In Finland, the Ministry of Education specifies computer science as a compulsory subject at the stage of general studies (first year) for students in mathematics, natural sciences, and economics, and at the stage of advanced studies for students in social sciences, education and physical education. In Britain the University Grants Committee (UGC) has recommended that all undergraduates should have some education in the use of computers, feeling "that the spread of computers into everyday life needs to be accompanied by an understanding of what they can and cannot do, and by an assessment of social problems arising from their use".

Some universities in Japan have computer centres specifically installed for educational use, and the teaching of computer skills to non-specialists is quite widespread. In the United States a number of colleges and universities have gone as far as requiring all their new intake, regardless of field of study, to purchase microcomputers, with the cost (discounted) usually being included in the tuition charges. The expectation is that the students will use their micros for at least part of their work in all their subjects.

As well as computers, higher education institutions in America use other forms of information technology in liberal arts curricula. For example, Rio Salado Community College (Phoenix, Arizona) has no campus but offers classroom courses in lower division general education and liberal arts as well as occupational programmes to over 2 000 students a year. The school uses public and commercial television, cable television, its own public broadcasting radio station, audio teleconferencing, slow-scan television, video and audio cassettes and telephone to serve its students. Again, one of the United States' most futuristic programmes is at Columbus (Ohio) Technical Institute where undergraduate liberal arts courses are offered using live, interactive cable television together with videotape. The system is called QUBE, and during the interactive sessions students viewing the television course can respond to questions posed by faculty by pushing buttons on a hand-held keypad device. Student responses are relayed to a computer in the television studio which summarises responses for faculty immediately (Lewis, 1983). While extremely innovative, the QUBE experiment in Ohio has not yet been duplicated widely elsewhere in the United States.

Despite all these instances, it must be said that the introduction of the new information technology in higher education is still far from being completed. Computer-Assisted Instruction in colleges and universities is being viewed very cautiously and adopted very slowly in most countries.

Regarding CAI, the Netherlands provides a good example (van der Drift, 1983). CAI is used in more than thirty courses at 12 of the 14 universities in the Netherlands with about 6 000 students participating. According to this study, "An initiative of five universities to purchase a dedicated CAI system and operate this in co-operation has not (yet) succeeded..." due to various institutional and government budget restrictions. Present CAI efforts have been assessed, in terms of quality, as falling "very far short of its potential". Cost comparisons included in this Dutch study of CAI versus traditional instruction show CAI costs per student contact hour to be substantially more than costs of traditional instruction unless relatively large groups of students participate (Akkermans and Moonen, 1982).

Elsewhere, a number of countries (Belgium, Luxembourg, Sweden, Finland as well as the Netherlands) have experimented with an American CAI system – PLATO – developed by Control Data Corporation in conjunction with the University of Illinois. These experiments have been generally limited and short-term in nature with little widespread impact. PLATO continues to be used as a CAI system (with substantial amounts of higher education courseware available) at a number of United States colleges and universities.

More extensive use of CAI is reported in Great Britain, especially in higher education. It is used extensively in the operations of the British Open University where they see great long-term educational potential because of its interactive ability for individual students, its capability of patient, instant feedback, its simulation potential and its communication and database capability giving students quick access to information. It is, however, expensive (O'Shea, 1983).

In Scotland all higher education institutions are reported to have CAI equipment, and in Japan it is used extensively in the national technical colleges. Italy also reports slow progress but growing interest, especially in university-based research projects on CAI (at the Universities of Milan, Genoa, Naples, Catania and Bari). More research on its effective use is now under way in such places as the Institute for Computerised Learning Environments at the University of Stockholm, the Computer-Assisted Learning Research Group at the British Open University, and the Computer-Assisted Instruction Laboratory at the University of Paris VII.

MORE UNRESOLVED QUESTIONS

As policy objectives are identified and resources allocated for implementing them, the economic concerns grow stronger. How much will it all cost? For what benefits? Who will pay? For how long? Future trends in the introduction of the new information technologies in education are already acquiring substance, yet, despite this, the matter of assessing costs and benefits remains a difficult one for the economist. Most of the available data are on expenditure rather than costs – in particular, there is virtually no information on opportunity costs; while little is known about the extent of resources invested by non-public or non-formal bodies, and, therefore, the balance between public and private expenditure. Furthermore, the much-voiced argument of the irresistible decline of hardware prices is losing ground as the new production seems to obey a different evolution of the market, with the price-to-power ratios decreasing more often than the prices.

To complicate matters, the "benefit" side of the equation is proving to be as elusive as the "cost" one. Some of the reasons are familiar. They are raised by those who see the functions of education in larger terms than just teaching and learning, thus making eventual "technological" benefits hard to assess. Other reasons are novel as they relate to specific lines of policy. A case in point is the current emphasis on investment in the education of specialised manpower. The trend, already strong in schools, is dominant in higher education. Given the current uncertainties in medium- and long-term forecasts for specialised manpower – for technicians and, especially, for professionals – the "benefits" attached to current priorities in investment look even more uncertain.

From what we already know, it might be tempting to list Member countries according to the relative size of their current investment and the quality of learning ensured by the equipment (and eventually the software) available to the pupils; but at present this would, at best, be premature. In fact, for all we know of the impact of the information technology on learning processes, each of the achievements can be equally good or bad for the learner. Nevertheless, alongside their economic value for education, the educational potential of the NIT will have, in the end, to be measured in terms of learning benefits. Hence, their effect on pupils must remain central to all policy considerations. The next chapter in our review will, therefore, concern itself solely with the impact of this new technology on learning.

Chapter III

THE IMPACT ON LEARNING

This chapter is on the impact of the new information technologies on learning processes in formal education – more specifically in the classroom. The readership we have particularly in mind is those in charge of designing, planning and managing educational programmes; our approach, therefore, will be a pragmatic one, addressing those questions that loom largest for them.

To attempt answers to such questions means, essentially, assessing the implications of introducing information technology in terms of three broad issues, each related in important ways to the organisation of the institutional education system. The first is the chronological organisation of learning. In which ways does the technology alter the speed at which pupils usually learn? How does it change the age-targeting of institutionalised learning? What is its impact on education's traditionally sequential organisation? The second issue is the contextual organisation of learning. As in other instances, school learning involves interacting with humans as well as with learning tools. In which ways does information technology alter such a context of learning? With what effects? What if the technology replaces the teachers? What if it limits the social interactions with the peer group? How is the technology perceived by the young learners? The third issue is the topical organisation of learning. How could the knowledge and skills taught at school be modified by the information technology? What becomes of the basic skills? What new skills have to be learned? What cognitive prerequisites are needed by what new learning? What is the transfer value, what are its cognitive consequences?

In addressing these matters we are going to concern ourselves with learning processes in the classroom rather than learning in general. Our data base is information gathered in research and educational experimentation on the development of learning that is, or might be, relevant to the world of formal education, particularly in primary and secondary education. This narrows our selection of topics, and also narrows the definition of the technologies considered. The bulk of data available on "information technologies" and learning processes relate almost exclusively to computers and especially to micro or mini computers. This is the current bias in the "technological" working agendas. We must also start with a central assumption on the nature of learning and of the forces and factors shaping it. This says that learning does not take place in a vacuum, that the process of learning depends on more than just the nature of what is to be learned and the ability of the learner to perform. When absorbing new concepts or mastering unfamiliar skills any individual is also reacting to a multitude of other actors and factors – visible or invisible, silent or vocal. Any intervention intended to develop or modify learning processes by altering their human and technological environment, cannot but acknowledge the existence of these "other" active agents. They are not difficult to recognise: they influence the lifelong learning whereby the child grows into an adult, and individual life patterns are constructed for work, leisure, family and social life, until the end. They are as tangible as the family, the school, the peer group, the work place, or as vaguely perceivable as the networks of powers and concerns that shape all our life conditions.

The new information technologies do not eliminate the dependence of actual learning on factors other than the learner's aptitude to learn. But the question deserves to be asked whether, together with any specific effect on the learning aptitudes as such, they can change what is learned; and, if so, how and to what purpose.

Perhaps the largest potential held by the new information technologies is in terms of quantity: they can increase beyond imagination the amount of information accessible to the ordinary people, by increasing the possibilities of storage, transmission, diffusion and retrieval. Perhaps the single most important challenge this creates for learning is in terms of quality: how can any single citizen learn to manage this new possibility? Our society is already information rich. Already learning processes are conditioned by information flooding the homes, the workplace, the school, the community. What are we to expect if the amount of information increases yet further, if its degree of coherence, already small, decreases even further? In education, this debate on the quality of learning can be seen as touching directly upon two aspects of its institutional mandate: the chronological organisation of learning – essentially a question of curriculum – and its management on pedagogical grounds.

In terms of timing, some of the (interrelated) questions raised more often in terms of curriculum concern its targeting to the age of the pupil, its sequential organisation and the speed at which specific knowledge and skills can be acquired. Most of the curricula, especially in basic education, are designed on the basis of some developmental assumptions on the cognitive abilities of the pupil; for instance, that certain notions and certain skills cannot be acquired before a certain age. Another widespread assumption sees learning as essentially a cumulative process where notions and skills are acquired through a carefully balanced sequence of steps from simple to complex. The extent to which these assumptions will survive the impact of the technologies, and the extent to which they will be invalidated, transformed, expanded by them is largely what this chapter is about. It will embrace, too, the impact the new technologies can have on the definition of disciplines as such, and hence, on the cognitive performance of the pupils, and how, indeed, they can change the pedagogical pillars on which the institution of education stands. These, with other matters, we shall pursue to the point of addressing a recent assertion that "computing as a resource may give the teacher back his proper function, of showing the pupil how to do without him" (GIDES, 1983).

THE TIME DIMENSION OF LEARNING

It has been observed in a variety of circumstances, at different levels of schooling and in different learning situations, that, when learning is computer-based, the learning itself is accelerated. Students have been found to learn more, retain more or learn the same amount faster using computers (e.g. Bracey, 1982).

Besides (rare) quantitative confirmations by bodies such as the California Testing Service, the wealth of evidence put forward to sustain the claim remains unmatched by the reliability and validity of the observations. What exist most in this area are teachers' reports. When computers are introduced in classroom teaching, it is not unusual to have reports of pupils covering the year curriculum in much less time, to the extent of creating some perturbation in the organisation of the classroom. A Canadian teacher comments: "Some of the bright children are now wanting time alone on the machine. Maybe they are looking to escape into it and ignore other things...I am giving them some lone time but they are having to come back and teach the rest of the group. I feel that I must stop them from getting too far ahead, for then, they tend to say that the other kids do not understand. This way they are bringing the group along with them" (Burnett *et al.*, 1983).

At times the gain in time is expressed by a general feeling of "easiness". Examples could be found at the intermediate schooling levels, where, for instance, a teacher has reported on a LOGO experience, that "using co-ordinates on the computer made the learning of latitude and longitude in geography easy" (Burnet *et al.*, 1983). From the same report, a grade 6/7 teacher writes: "I have taught all the Grades 6 geometry and gone beyond the curriculum to the Grade 8 level of angles. When I was teaching a lesson on lines, points and vertices the children said they already knew it. This is a result of working with the computer... I feel my class is ready for recursion in understanding although they did not have the maths concepts yet".

At other times, the findings are of a more concrete nature. A recent report, for instance, states that at the post-secondary level, "in every study in which Computer-Based Instruction substituted for conventional teaching (either for a unit, a module, or for an entire course), the computer did its job quickly – on average in about two-thirds the time required by conventional methods. It is clear that the computer can function satisfactorily in college courses and at the same time reduce time spent in instruction." (Kulik *et al.*, 1980).

Although far from scientific soundness, the anecdotal evidence is particularly compelling in the case of remedial learning. In a number of instances, the low achievers, the school failures, have been observed to learn, at least in the basic skills, in a relatively short time where years of traditional teaching/learning situations had failed to produce any noticeable results (e.g. Naymark, 1983).

Faced with such an increasingly suggestive body of evidence, a first, rather basic, question arises as to its possible meaning: does the technology produce qualitatively different learning processes or does it just change the perspective with which we observe what are essentially the same processes and mechanisms as in "machine-free" learning environments? Does the technology solicit the development of new brain functions or is it merely eliciting a different organisation of otherwise familiar human functions?

It can very well be, for instance, that the time spent to learn is shortened simply by way of rationalising the learning situation – most ordinary learning processes in the classroom are rather wasteful in terms of time. One could easily imagine how information technology could hasten them by eliminating hollow periods, by keeping the learner active and motivated, by presenting the information in ways that are easier to assimilate. It can also be that the new technology brings to the awareness of the learner elements important to the learning that would otherwise go unnoticed. In the words of a French author, describing the possible reasons at the root of observed performances in learning LOGO, "the computer's capabilities are likely to modify the pattern of child development, by speeding up some of the stages in it. This precociousness is probably associated with a combination of beneficial ways in which the computer can help certain learning processes along. Those beneficial aspects are interactiveness, the learner's being continually stimulated, instant self-correction, independence, creativity, and the learner's intensely active involvement" (Naymark, 1983).

Next to the impact on the time spent on learning, another strand of similarity among observations concerns the onset of certain learning processes, particularly on the apparent modifications of the age at which notions or skills can be learned. The work of Piaget, Bruner and others has demonstrated convincingly that cognitive development takes place in predetermined sequences, holding two main characteristics: their relative positioning is irreversible; and they mark a progressive detachment of the learner from the concrete environment towards an increased reliance on "inner" mental structures. Among the researchers who have applied such understanding to "learning by computers", the name of Seymour Papert has come to acquire a major prominence, particularly in relation to the LOGO system, in itself an application of the Piagetian model of concept formation in children during their concrete operational stage.

Developed at first in laboratory conditions, LOGO has acquired of late a tremendous visibility of almost mythical proportions. Its reputation is built not only on what it seems to confirm of the established models of cognitive development, but also, and perhaps more importantly, on what it seems to refute or qualify in them. LOGO has been among the first computer-based learning systems to produce additional ammunition for those who, on the basis of non-computer-based research work, have long cast doubts as to some central hypothesis of established models of cognitive development. The major debate worth mentioning here is that of the alleged inability of young children to perform at formal levels of thought. Many educators have concluded from Piaget's work that children lack the conceptual structures needed to operate on abstract notions, an ability which is not supposed to develop until the mid-teens. In the recent years the evidence has multiplied on the cognitive age-marking introduced by Piaget, being influenced (and possibly changed) by factors other than cognitive, of social and cultural nature (e.g. Doise and Mugny, 1981). This newly acquired understanding has not had much influence in modifying the original belief, which has been further strengthened by findings such as those from clinical research showing correlations between cognitive stages and physiological phases of neuronal growth in children (e.g. Toepfer, 1982).

The LOGO-based experience has since opened the gates to a multitude of research work throwing more systematic doubts on this central hypothesis. In the words of Seymour Papert, the Turtle, the main tool of communication between the child and the computer in the LOGO learning system, makes it possible to uncover the unexpected: "My goals are education, not just understanding. So, in my own thinking I have placed a greater emphasis on two dimensions implicit but not elaborated in Piaget's own work: an interest in intellectual structures that could develop as opposed to those that actually at present do develop in the child, and the design of learning environments that are resonant with them. The Turtle can be used to illustrate both of these interests: first, the identification of a powerful set of mathematical ideas that we do not presume to be represented, at least not in a developed form, in children; second, the creation of a transitional object, the Turtle, that can exist in the child's environment and make contact with the ideas." (S. Papert, 1980).

Still in the area of mathematics learning, it is worth adding to Papert's the conclusions drawn from a recent report summarising the results of a number of researches, not necessarily computer-based. "Children have significant conceptual understanding of mathematics concepts at much earlier ages than had been believed previously. Early understanding of these concepts is incomplete and largely implicit, but it is clearly not totally lacking, which means that instruction should be designed to capitalise on important conceptual building blocks that children have, rather than assuming that they have no cognitive basis for developing understanding of important abstract principles." (FBPCS, 1983).

The evidence is suggestive and multiplying. In a number of countries systematic investigations in this area are currently being carried out. They show the enthusiasm, sometimes the euphoria, generated by the promises implicit in the earlier findings. Yet a word of caution has to be said, for some of these conclusions may be biased by expectation and not the result of objective assessment.

Surveying a number of French experiments, a recent report prepared for the OECD describes the situation in the same critical terms as could be applied in other countries.

> The material available at present is not at all rigorous, either as to conditions or still less as to results achieved, so it only warrants some initiative and rather broad comments. Every investigation concerned with younger children emphasizes the ability to look ahead that is involved in programming, because it implies being able to imagine beforehand what the outcome will be of the successive operations necessary to achieve the intended results. Children do look ahead to some extent, but their strategies (empirical, analytical...) can vary and achievements are mixed... Underlying these experiments, of which there are more and more, is a major pedagogical insight: a child's heuristic activity, brought on by having him/her work on this kind of intuitive geometry and logic, is likely to transfer to other, more academic activities... early reading (by about age four) can be taught by a technique that has already been shown to work relying on the stimulus provided by the interactiveness of the computer. The findings of research along these lines will be worth close attention...
>
> For older children, the committee assessing the computer option in the lycées has made various comments on learning to program. Unguided, spontaneous programming (which children can do because a certain number of algorithms can be programmed very quickly) results in programs whose complexity reflects whatever level of capability the child has reached for reasoning in the abstract. A child who can grasp a purely sequential process will have no difficulty in writing a set of "do" and "if" instructions. One who can grasp iteration will have no difficulty in including loops... There is probably a need to check whether any attempt is or is not being made to inculcate knowledge via computing beyond the pupils' usual level (Naymark, 1983).

However, whatever relative weight we attach to these various studies *vis-a-vis* the sequential issue, the results indicate the great potential of the technology *vis-a-vis* the processes of learning.

In this it has a double role: as a modifier of the processes, and as an instrument for understanding them. Its introduction into the learning environment leads (according to modalities still largely unknown) to changed performance by the learners, these changes indicating some modification of the underlying processes of learning and/or of their cognitive and motivational determinants. This, in itself, puts us on the road to a better understanding.

As to its second role: by providing the technological support for increasing the flexibility and richness of the learning environment in terms of information, exploration and discovery and, most of all, by making data collection and analysis fast and undemanding, the technology qualifies as an important tool of research on the effects it produces. This double role of the technology on learning is one of the conceptual pillars also in the following section, which examines its impact on pedagogy and the institution of education.

THE CONTEXT OF LEARNING

The quest for what makes learning possible discloses the great importance of contextual factors, such as the presence of a "tutor", interaction with peer groups, or specific technological supports. Yet in studies of learning by the new information technology this aspect has received little attention. What references there are tend to cluster around topics such as the merit of individual vs. group learning, or the personal reaction of the young to the computer. Some North American studies report favourably on the affective/emotional outcomes of "learning with computers" or speculate about "useful social effects when co-operation is supported rather than competition" (Crossley, 1983).

Scandinavian experience from the upper grades of the compulsory school, from general secondary schools and from upper vocational institutions, shows that there are pupils (mostly boys) who are highly motivated to learn by way of computers and ready to use their time and energy to find out ways to develop themselves in the new skills (Ruoppila, 1983). These observations are not paralleled by any serious enquiry into the subsequent cognitive and social development of the students; they seem, however, to indicate an improved level of social interaction and a transfer of benefits to the advantage of students' school work in general. An official publication on the evaluation of the Swedish project PRINCESS (aiming at studying the feasibility and desirability of learning by computers in schools) is explicit on this point: "The various computer aids used have been found to improve the quality of teaching and learning ... Project work is made easier by computer aids. It was also found that computer aids could be usefully employed in group work involving two or three students. Word processing was the only connection in which students did better working individually. Co-operation between students improved in most cases." (CLEA, 1983).

But even word processors do not necessarily lead to isolated learning, if it is only the organisation of the learning environment that changes. A small-scale Canadian study, for instance, has found that "when children had access to their own private terminal there would be little interaction about their writing tasks because they would be so eager to work on their own projects." (Kane, 1983). This apparent confirmation of the Swedish findings on the use of word processors is, however, confuted by findings such as those of another Canadian study on the effects of a second monitor standing facing the pupils at the head of the class. This second monitor was found to generate intense socialisation between the users of the simple word processing facilities and their classmates. "Perhaps", the author comments, "having a limited number of terminals for word processing use would be a blessing in disguise..." (Logan *et al.*, 1983).

Other observations of Canadian classrooms confirm that "independent" learning with computers is not necessarily synonymous with "isolated" learning: "Observations in classrooms with microcomputers available for regular use indicate that the keyboard and screen become the focus of small group relationships among students who are intent on solving problems. This phenomenon is contrary to earlier predictions, based on experience with library carrels and with senior students intent on academic studies." (Crossley, 1983).

If the pupils and students like the computer there must be a reason. Very little is known about this apart from anecdotal personal reports. There are a few observations to the effect that, whatever their determinants, the reactions could be, for instance, class-dependent. In a survey of experiments in French primary schools "original investigations into childrens' perceptions of the computer show that drawings by children from comfortably-off backgrounds are fairly stable over a full year spent using the computer, while drawings by less privileged children evolve from an anthropormorphic picture of the machine (e.g. spiderman, etc.) towards a more instrumental one" (Naymark, 1983). Children's reactions can also depend on the degree of familiarity with the computers: the more familiar the child the more realistic his/her representation of the computer's possibilities (INRP, 1981).

Observations of older pupils in remedial education suggest that computers might have specific motivational virtues: "in a context of all-round failure at school, computing as an activity strongly stimulates and motivates pupils. The positive reinforcements, the ability to check out an abstract activity immediately, the scope for creativity, the ability to reverse the traditional teaching situation by instructing the computer, all help the pupils to get out of their anti-school attitude and build up their confidence in themselves." (Naymark, 1983).

Similar positive reactions to the computer are reported by a Canadian teacher: "Watching many learners use courseware leads increasingly to the belief that the learner learns more and more happily when he or she has control over his or her own objectives and methods of learning" (Godfrey and Sterling, 1982). Requested to identify the most satisfying use of microcomputers in their classes, 74 per cent of Manitoba teachers indicated "motivation and interest of the students" (MTS., 1983). Other positive attitudes are reported anecdotally from Scandinavian countries where the introduction of the computer in the classroom has often generated "clear positive effects on teacher-pupil relationships, due to the enthusiastic feeling and common interest which make the interaction democratic" (Ruoppila, 1983).

However patchy, the above data certainly indicate that interactional and organisational variables are increasingly appearing as major factors in determining the kind of learning taking place via computers, although, again, the specific modalities of the impact are not as clear. Our conclusion (such as it is) for this part of our review must, then, be that there is a growing awareness of the contextual organisation of learning as an area of enquiry as important as it is uncharted. As a modifier of the social environment and of its support structures, information technology can safely be expected to influence learning; but considerable research and experimentation is needed to ascertain the kind of impact thus produced, the kind of changes imposed on learning, the kind of learners likely to be affected more than others and in which ways.

THE CONTENT OF LEARNING

Of the little information that exists on the impact of information technology on learning processes, this is the area where most of it can be found. This polarisation of research efforts reflects the central mandate of education, namely the equipping of the young with the basic knowledge and skills to lead a socially integrated adult life.

Within this general context, the bulk of research generated so far has stemmed from a more specific concern: the acquisition of basic skills. Two main trends can be identified in this area: one aims at clarifying the impact of computers on "old" basic skills such as reading, writing and numeracy; the other aims at analysing the emergence of possible "new" basic skills, more directly linked to the cognitive demands and possibilities opened up by the new technologies. The debate on the cognitive value of computer programming skills is central to the latter trend. In both cases, strict cognitive concerns are paralleled by an equally strong emphasis on computers as a tool to improve the efficiency of the education system.

Reading

In the realm of learning to read, information technology can influence the process in a variety of ways: it can operate on the learning environment, on the motivation of the learners and their tutors. It can also influence the process by introducing new content materials and new technical supports, as well as by making different teaching/learning approaches possible.

The issue of reading skills as content-bound is an old one to which a number of analyses have been devoted. Some of them have been articulated in terms of quality and familiarity of the schools' reading materials. The contribution of computers to the quality issue is far from clear. Whatever the diagnosis of the merits of current instructional material, the question remains unanswered as to what beneficial effect could be expected by the technology. A priori, there is no reason to suppose "that the pedagogical acumen of people who write computer software is going to be any greater than that of people who write paper-and-pencil workbooks" (Anderson, 1983). In that, computers do not introduce new terms to the debate, but re-propose concerns already established in a different form, such as software development and authorship strategies.

The issue of familiarity of school reading, on the contrary, qualifies as highly relevant and specific to the possible influence of the NIT on reading. A question central to the acquisition of reading skills is whether any suitable materials of instruction can be used to teach skills of reading and writing. What has been going on in most Member countries in recent years provides a positive answer to it. In most schools the materials used to teach to read have not ceased to multiply and diversify. Today's repertoire includes a large variety of textbooks, mimeographed sheets, games and other instructional tools. Without any doubt these developments are a plausible solution to some of the problems at the origin of recent and less recent school changes. Decentralisation, autonomy, multiculturalism, alignment with real-life concerns, have all led to increased curriculum differentiation across schools, as well as increased variety across classes.

The extent to which these changes are also solutions to the problem of the quality of reading skills is much less clear. A recent line of research suggests strongly that the proliferation of different materials, by exposing the learners to an increased amount of unfamiliarity, can severely offset the benefits gained from their quality (Hirsch, 1983). The quality of a text – the model claims – makes a difference in comprehension only when the learner is familiar with its subject matter. Familiar reading material produces the expected effects: good style is all the more helpful to comprehension when the content is difficult. Exposure to unfamiliar material, however, tends to produce reading performances that are counterintuitive. Here good style contributes little to the quality of reading.

Subject to confirmation by other researches, the role of content familiarity on the acquisition of reading skills could well be a crucial one in the area of information technology. As noted before, perhaps the largest potential of the technology is for the quantity and variety of information it gives access to. To what extent this new power could turn into a Pandora's box for the acquisition of basic skills such as reading, is a question deserving careful scrutiny.

The issue of reading skills as support-bound is also one that qualifies for close analysis. The intuitive idea of an unavoidable specific influence of technologies such as the computer on the acquisition of reading skills begins to be substantiated by clinical research showing how, when reading from a visual display screen, the brain produces wave patterns different from those corresponding to reading from a printed text (Logan *et al.*, 1983). Some research is also investigating the possible differential effect of learning by computer on various related subcomponents of reading skills such as word recognition (the speed of which seems to increase) and word comprehension (the level of which seems, on the contrary, to decrease)(Collins, 1982).

Finally, another area of possible impact by information technology is the teaching/learning strategy whereby reading is taught in schools. Despite the considerable progress made in related fields such as in linguistics, the approach to teaching reading has undergone little change for many years. It was, and still is, essentially phonetic. Children are taught to learn to read by matching written symbols to sounds. Even the innovative "Writing to Read" computer-based reading and writing instruction system (Tolbert, 1985) which starts (successfully) with kindergarten children is based on this approach. Over the years, letter recognition has been largely replaced by syllable or word recognition as a counterpart to sound. But the relationship has remained phonetic. Other approaches through grammar or meanings have remained, for good or worse, largely absent from the classrooms. To the extent that computers have no voices (in itself a temporary condition) such approaches may even yet be replaced by others whose effects on the acquisition of the skill are still uncharted.

This doesn't look much of an inventory, but it is about all our information adds up to. If so little is known about the impact of computers on the acquisition of reading skills, it is because correspondingly little is known about the deep nature of reading, and this makes it next to impossible to discuss possible influences upon it. At best, reading is only "a partially observable, partially decomposable process, best conceived as a system of interacting component processes" (Anderson, 1983) which are far from being comprehended. Perhaps the most important impact of information technology could be expected precisely at this level, to make reading understood. So, research on reading difficulties, diagnoses of reading strategies and errors stand out among the main priorities in this area.

Writing

As for reading, the study of what makes writing possible, and at what level, has gone through several phases in recent years. The latest one is marked by a shift in attention from the product to the process – the result of empirical studies of writers' behaviour and the underlying cognitive processes. It is worth quoting the conclusions of one such enquiry: "All children can learn to write... Young children are able, given support and guidance... to adapt the powerful language learning strategies they employ in learning to speak to the process of learning to write" (Gundlach, 1983).

In drawing a parallel between language acquisition and writing, we are not so much supporting those who claim a link between the two as seeking an illustration of where information technology could assist in the acquisition of writing skills. In learning to speak, the child has no other mechanical skills to master than the sensory motor control of his own organs. Writing with pencil and paper is much more taxing. The sensory motor control of arm and hand drains much of the resources of the child. How to concentrate on ideas, how to focus on structured paragraphs, how to retain the thread of a story, when so much effort is required just to draw letters and form words.

It is in this area – the writing skills of beginners – that the NIT are already having an impact on learning by way of the word processor, which eliminates most of the mechanics involved in writing. The effect on the speed at which the skill (in terms of syntactic and grammatical correctness) is mastered is particularly apparent in those children who have had difficulty with the normal practice – even the youngest of them.

Although much needs still to be done to understand why learning to write is facilitated by the word processor, there is a wealth of anecdotal evidence to confirm it. In primary as well as secondary education, pupils are ready to explain why word processors are better. With them, they say, there is less concern about making mistakes because corrections are easy (and can be made away from teachers' eyes). The text looks better, and this makes it easier to fix errors and ideas. Typing doesn't hurt the hand like writing does. (e.g. Naymark, 1983; Collins, 1982)

Such physical and psychological benefits are claimed by older writers as well. As a recent report puts it: "The psychological inhibitions of writing and rewriting letters or essays... almost disappear. Even spelling corrections become a form of 'debugging' rather than fault finding with penalties. There is enough empirical evidence in classrooms as well as in the offices of business and industry to illustrate the 'freeing-up' of the thought processes that takes place as a result of the relative freedom from the mechanics of writing and/or typing." (Crossley, 1983)

Having been freed from its dullest demands, writing can be learned in different ways – for instance, by experimenting with different strategies for composing essays. This is the objective of newly-available software such as the Essay *Outliner*, produced by Canadian teachers, whereby the students can either outline a sequence of topics, then expand them to create the essay or, alternatively, adopt a holistic approach from which to extract the elements of the structure or outline. This approach responds to the importance of providing writing alternatives especially in the primary and early secondary years of school when the creativity of all students should be fostered, while skills are taught.

As with reading, not much systematic knowledge exists as to the cognitive processes involved in writing and, although not many warning signs have shown up as yet, the risk remains that the use of computers may provoke undesired side effects. As research progresses, awareness grows of the complexity of skills subsumed under the generic label of "writing", and this implies that there is a wider field than we know of where such effects may be induced. The sharp differences ascertained between novices and expert writers is one of the new avenues of investigations in this area; difference in the skills underlying the writing of short, as opposed to long, texts is another.

As with reading, the contribution of information technology to writing can be expected at different levels. It can facilitate the acquisition of the skills as we know them. By the same token it can have other unforeseen effects on what is still unknown. Perhaps, even more importantly, the new technology can be used to understand the processes themselves, by reconstructing the strategies developed by the writers to write, to correct, to revise.

Numeracy

A recent report from the United States (Davis, 1983) describes the position as to mathematics learning, and this could well be generalised to other countries: a very large number of students can learn considerably more mathematics than they typically do at present; the discrepancy is particularly pronounced in the case of mathematically gifted students; many students are in fact learning far less than they are believed to be learning. In assessing the impact of information technology in this area, it may be useful to look at the reasons alleged to be at the root of these observations.

Some critics trace these shortcomings back to the widely-based (and incorrect) conceptualisation of learning mathematics twenty or more years ago, whereby "knowledge" was measured by the selecting of correct responses to a relatively small collection of questions (Davis, 1983). Currently, the new wave of research in this area is emphasizing what had long been pointed out by Piaget and others, namely that it is a mistake to focus only on "right" and "wrong" answers, and ignore the reasons why people select different ones. In other words, the new generation of research on numeracy, similarly to that in reading and writing, has shifted the emphasis from the products back to the process.

Another reason often given for the less-than-satisfactory results in mathematics learning is, even more basically, that the approaches used so far have not adopted teaching/learning strategies specific to children. Speaking of modern mathematics, S. Papert says that "it did not come from a process of invention of children's mathematics but from a process of trivialization of mathematicians' mathematics". (Papert, 1980).

The combination of the two trends of thought might find in computers a particularly useful tool to further understanding of the subject and to inspire new approaches to it. The computer has already been given an important place in the learning of mathematics concepts, for instance by way of the LOGO system. For older children, pocket calculators are already performing a useful role in animating the debate, if not in providing answers to it. In the area of remedial education, computers have been used to analyse error generations. This has provided important information on thought processes which has led in turn to improved learning.

The field where most of the data have been gathered is also where there is less certainty as to the beneficial effects of computers on learning: the learning of mathematics by drill-and-practice. A typical result would indicate that drill-and-practice has a positive effect on computational mathematics, but that increases in conceptual understanding of mathematics are sometimes greater, sometimes smaller, than for control groups (Ragosta *et al.*, 1982).

In this area, as in others, the potential of information technology is as great as the need to understand the variety of observed phenomena and the possible development of new approaches to learning. In particular it is important to analyse what works and what does not work, in which learning environments, with which learners and which technologies. In this context, in mathematics as well as in reading or writing, given the accumulation of uncertainty as to the processes underneath, generating the right questions is possibly more important than finding answers to meet what look like the most urgent needs.

THE EVOLUTION OF BASIC SKILLS

Crossley has recently observed that: "A continuing dilemma for curriculum decision-makers in all school systems is created by the concept of basic skills. There is adherence by many people to the idea that reading, writing and arithmetic are the "basics" of education. Conservative or traditionalist educators tend to combine this notion with an emphasis on drill and practice, and uniform standards. On the other hand, education should prepare students for contemporary society and/or the future, and should do so for as many of the students as possible. The question of what skills are to be offered by the school system and the best processes of teaching and learning to achieve not only skills but those higher order goals expected of education are issues that tax the judgement of educators and politicians." (Crossley, 1983).

Hirsch brings the issue of basic skills down to its own basic level, its link with literacy: "Literacy is not just a formal skill; it is also a political decision. The decision to want a literate society is a value-laden one that carries costs as well as advantages." (Hirsch, 1983)

Between them, these two authors pinpoint three of the main issues in the debate on basic skills and on literacy. One is that the definition of basic skills is largely one of convenience, dictated more by the supposed needs of the time for integrated social life than the supposed needs of single individual lives. The second is the translation of convenience into uniformity, one further step away from individual specificities, perhaps one towards social equity. The third is the notion that the promotion of literacy carries costs as well as advantages, for individuals as well as society.

The new information technologies and the knowledge and skills related to them have come to occupy a place of prominence in the revived debate on basic skills and on literacy, where they are often seen as fulfilling a possible double role. They are counted upon to insure the acquisition of "established" basic skills and identified as indicators of new ones to include in the making of the new literacy. A first corollary concern in the debate relates to their possible role in making some basic skills obsolete. A second one bears on their possible impact on the gap between the satisfaction of societal needs and the respect of individual differences. A last one, implicit in many discussions, looks upon the NIT as the "miracle" remedy to make education succeed where old ways have failed.

Enough has been said in this review to confirm that information technology has the potential to play all the roles expected of it, within reasonable limits. The fact that not much is known as to the specific effects of computers on learning is only a temporary drawback. Given enough investment in research and experimentation, understanding will undoubtedly be reached as to their functions at all levels.

The evidence adduced so far indicates that computers can be of assistance in the teaching/learning of the "old" basic skills. Reading, writing and numeracy can be facilitated by the use of the computers, although it is becoming clear that the observed benefits might come at a price. Speed of reading might be increased at the expense of text comprehension. Multiformity of reading materials can be achieved more easily, possibly at the expense of literacy levels. Literacy in the 3Rs could be acquired earlier in life at prices still unknown in terms of individual development. Writing can be facilitated at the expense of sub-skills such as grammatical or spelling literacy. It could even be made obsolete by the increased availability of visual (graphic) forms of communication. Numeracy can be achieved with less effort and in less time, but possibly at the expense of the specific thought processes developed from some number manipulations.

But the impact of the technology goes well beyond its possible influence on basic skills. It can create the need to acquire new ones. Some likely candidates are emerging more forcefully than others. They are linked to the largest potential of the technology, access to information. Put plainly, once information and data can be retrieved at will, memory and recall skills, central to established teaching/learning methodologies, will become peripheral to learning processes. Instead, other skills will acquire importance. The ability to deal effectively with novelty might become as important as the ability to deal effectively with repetition. Working with computers often develops a generalised attitude of enquiry, of "trying out", rather than relying unquestionably on the knowledge pre-packaged by the teacher. The need to develop personal learning strategies might become a must to orientate oneself amidst the options available. The list will get still longer in time.

As for "old" skills, the new ones will not necessarily come for free. The focus on individual learning might be detrimental to those who cope badly with learning without a human coach. The multiplication of options and possibilities might handicap further those who, in the absence of firm guidance, tend to "get lost" or to resort to earlier learning attitudes that are not necessarily beneficial. In short, the strong learner might grow stronger, the weak weaker. The consequences for uniformity, individual differences and, in the end, social equity might be substantial.

Learning to program a computer, most seem to believe, will do more for people than making them acquire a basic skill: it will expand their intelligence, it will develop their brain, it will give them a thorough, sharp mind. Humans will then grow all the wiser to avoid "technological" prejudices.

The "Other Virtues" of Computer Programming

Although caricatured, the issues raised in the previous paragraphs are very real in their substance. A number of policy decisions as to the introduction of computers in education rest on the assumption, at times more explicit than at others, of the "other virtues" of computer programming. Many heated debates on the curricular value of computer programming develop around the belief of some, and the disbelief of others, in the therapeutic value of this skill for the pupils and for the institution.

As a recent report puts it: "There was a time when it was generally believed that in learning how to do geometry, one learned the generally useful skill of thinking deductively and rigorously. Similarly it was believed that in learning Latin one disciplined one's mind and made it thereby more conducive to learning in general. More recently, it has been suggested that the teaching of computer programming might be an effective vehicle for the teaching of generally useful cognitive skills. There is very little evidence that the expectations for geometry and Latin were warranted. What reasons are there to expect that the learning of programming would produce more substantive results?" (Nickerson, 1982)

The debate around computer programming rests on a scant data basis indeed. Little is known as to the nature of the skill or its cognitive benefits and even less on the "transfer" value of whatever is specifically acquired. Without doubt this is an area where investigations, thus adequate investments, are needed especially urgently. Among the many aspects of the problem to analyse, important ones, with immediate relevance to education, would be: the definition of the concept of computer programming; the cognitive prerequisites to its learning; its cognitive consequences, including the issue of transfer.

As with many other skills when examined at close range, computer programming ceases to look like the convenient unitary label it is often taken to be and reveals its real nature, which is very complex. Defined as a body of knowledge or a skill to master, computer programming can entail different cognitive prerequisites and have different cognitive consequences depending on a number of factors. Among them, the programming language is as influential on learning as is the specific kind of software it is meant to produce. The hardware configuration, the learning environment, are all additional, and important, factors to consider when establishing learning approaches in this area, or when assessing the learning taking place.

One way to analyse the cognitive prerequisites of computer programming is to study possible correlations with other and better known cognitive abilities and factors. After having surveyed the scant literature in this area, a recent report draws a tentative diagnosis: a number of cognitive skills have been identified as possible correlates to programming skills but only very few have been the object of investigation so far (Pea and Kurland, 1984). The list includes items such as memory capacity, analogical reasoning (possibly a crucial skill for transfer), conditional reasoning, procedural thinking, temporal reasoning. Among the few investigated, mathematical abilities top the list, followed by IQ correlational studies. In both cases the typical correlation found is either modest or unclear. In the words of the reviewers, "to our knowledge there is no evidence that any relationship exists between general maths ability and computer programming skill once general ability [intelligence] has been factored out. Nonetheless, general maths ability *per se* cannot yet be ruled out as a possible prerequsite to the successful mastery of computer programming skills".

The correlation with IQ has been explored only indirectly, in relation to the ranking or scores in programming courses rather than with programming skills *per se*. In this context, adults' IQs have been observed to correlate, albeit modestly, with such indirect measurements. It is worth noting that no relationship has been established between the performance of adults on such scores and their subsequent performance in computer programming in the work place (Pea and Kurland, 1984).

Besides the difficulties inherent to the nature of the skills to analyse, still poorly understood, or the influence of outside factors, still largely uncharted, the study of the cognitive correlates of programming skills is beleagued by a number of other problems. Among the factors qualifying as major determinants of learning one could easily count the age of the learners and their degree of familiarity with the computers, prior to the tests.

Cognitive abilities by age are obviously a central issue in the debate on how and when programming should be taught in schools. A recent survey of U.S. evidence proposes broad tentative conclusions in this area (Becker, 1982). Children in grades K to 4, the report says, can learn rudimentary programming operations, particulary in special languages like LOGO, in which almost all operations are built from a few primitive operations. At about age 11 or 12, the report continues, a general improvement is observed in planning general structures and devising comprehensive computer tools, but only after a good deal of effort and guidance on the part of the instructors. Students in grades 6 to 8 seem, on average, sufficiently mature to understand the abstractions involved in programming. Older students, on the other hand, seem to separate into two groups: a small proportion who are personally interested in programming activities and a larger proportion who view the computer as just another subject in the curriculum.

Another report, surveying French computer-related experiments in schools, suggests that great caution should be used in generalising results by age, as the differences within same-age groups could be as large as the differences found between groups (Naymark, 1983). An in-depth analysis of a LOGO experiment in primary education has revealed that only two thirds of the children have no difficulties in mastering the concepts and the relative programming activities. The remaining third experience difficulties in learning the same concepts and usually abandon programming above a given threshold of complexity. On the other hand spectacular results, well above their usual school performances, have been obtained with no more than 2 or 3 pupils per class, notoriously shy and withdrawn.

Within a school population of more modest social origin, an experiment of computer-based remedial education has also led to differentiated results. The computer was found to be a formidable pedagogical tool to bring about improvements in the social and psychological make-up of the pupils. Its impact on their school performance was however uneven. Good, even spectacular results, have been obtained with no more than half of the pupils. With the others, improvements have been obtained only on some of their assessed deficiencies, such as in learning concepts of geometry, in overcoming problems of lateralisation, or in holding prolonged concentration on a task (Naymark, 1983).

In general the results reported in the literature on the learning of computer programming show a variety of outcomes ranging from enthusiastic, to cautious to negative ones. Some of the differences in the results have been claimed to derive from the different programming language used in the studies. With older learners, some say, the language chosen does not make a big difference in the observed outcomes. More important in these cases seem to be issues such as the resources available in the programming environment, how programming instruction occurs and the amount of program writing and debugging students engage in. (Pea and Kurland, 1984)

For children on the other hand, the computer language could make the difference between learning and not learning. Not much disagreement exists on children being more successful at learning LOGO than BASIC, for instance. Yet the issue of language *per se*, if taken too exclusively, could prove to be misleading. Perhaps, some authors say, it is not the language that makes the difference but rather its "programming environment". In this context, many of the alleged advantages of LOGO over BASIC as a language for children could lie in the sophistication of LOGO's programming environment (Pea and Kurland, 1984). For example, LOGO has a much more sophisticated editor, more detailed error messages, better debugging procedures and greater finesse in creating and manipulating files.

Yet other studies identify a main factor in determining performances in computer programming in the prior familarity with computers. It would be a truism to say that differential access to home-based computers could explain some of the better performances observed in schools. In addition to such common-sense observations, harder data are being gathered which tend to confirm the above hypothesis.

Studies on adult learning have shown in Scandinavian countries how, when learners have used computers in their daily work for some time, the skill of programming them is acquired at a higher level and in a shorter time (Ruoppila, 1983). Surveying a body of research work on novices vs. expert adult learners, another study confirms the existence of large differences between the performance of the two groups (Pea and Kurland, 1984). Among the most relevant results one could mention that the acquisition of high-level computer programming skills seems to be characterised by a giant assembly of highly specific, low-level knowledge fragments.

Additionally, large differences have been found in the way expert, intermediate and beginner programmers develop mnemonic strategies: for instance, experts cluster the keyword commands according to meaning whereas novices use a variety of surface ordinary language associations. Finally, a common result concerns debugging techniques: experts read programs for flow of control (execution), novices use line-by-line (as text) techniques. It is interesting to note that similar "strategic" differences phrased in terms of deep meaning or superficial connotations of concepts and processes are emerging from studies of novices and experts in the field of physics (Nickerson, 1982).

Although far from exhaustive, the data here analysed are convincing enough: the hopes on the cognitive benefits to be gained from computer programming skills might be, to an extent, unrealistic. Diversity seems to be the key word. The skills rest on an aggregate of subskills, the study of which has only just started. The cognitive prerequisites for acquiring them vary accordingly. Not all learners have them. The cognitive consequences also vary, depending on a number of factors, suspected rather than charted. Yet, a number of people in various situations have been observed to perform surprisingly well on computer programming tasks, suggesting important gains at the cognitive level. Clearly, computer programming has a cognitive value. It remains to be seen in which conditions,with what people and to what extent the expectations could be satisfied.

Given enough investment, in terms of time and research, it might well appear that computer programming can facilitate, without being necessary nor sufficient, the development of particular cognitive abilities. Planning, precision, generation and testing of hypotheses, formulation of problem-solving approaches, are all cognitive abilities involved in computer programming, in different degrees. Probably the learning of computer programming will prove to be of benefit to these more general cognitive domains. In the affirmative, the debate on the desirability to teach computer programming to all pupils, and, consequently, on the curricular status it should be given, could well end by endorsing a weak rather than a strong hypothesis as to its cognitive power. But even then the question will remain of whether the same cognitive effects could not be achieved without the computers and with other teaching/learning methodologies.

The question of the hidden costs and cost-effectiveness of information technology in learning is part and parcel of the debate on the cognitive aspects of learning basic skills, the old as well as the possible new ones. The question is also central to the general debate on the role and impact of the NIT on learning.

The evidence available tends to support the general contention that computers have an impact on learning processes. The same evidence, however, does not provide clear grounds as to what processes are affected most, in which learning situations, with what people. Such a situation of uncertainty as to the specific impact of computers seems to be determined more by the current understanding on learning (which is inadequate) than by an insufficient understanding of the technology.

Trends are emerging, however, which indicate how the situation might evolve in not too distant a future, under the combined effect of progress in the cognitive sciences, where research investments are growing, and enlarged introduction of information technology as support tools of experimental paradigms. The foreseeable picture of the learning sciences is therefore one where the technology can very well play a central role in fostering understanding, although, most probably, at a price.

The evidence already discussed shows the manifest value of the information technology as a working partner for the researcher. The same evidence, however, warns that the partner can grow rather demanding. Its hidden power rests on the ability, unique to the technology, to perform simultaneously the double role of "revealers" and "analysers" of learning processes. It will help unveiling the underlying dynamics of cognitive factors. It has also the power to analyse the processes quickly, effectively and at reduced costs. This double ability makes information technology extremely attractive for research on a cost/effectivness basis. Its appeal might however conceal its power to introduce important biases in the understanding gained through it on learning.

When using the technology as a "revealer" of learning processes, it will be inevitable to introduce a selection on the research targets. The processes most often observed will be those which are observable via the new information technology. Quickly, these will also become better understood among the possible array of processes on the research agendas. The risk of losing the others through the familiar chain of neglect, oblivion and, finally, denial is not unsubstantial. In what follows we show how similar is the power of this technology in teaching/learning situations, transferring to these other levels its unique ability to perform the double role of support for the processes and means for their analysis as well as the risks inherent in this ability.

PEDAGOGICAL APPROACHES

The field here under review – the relationship between technology-based and school-based learning – is one of many possibilities and few certainties. This just about sums up the state of current understanding of the impact of information technology on learning processes. First, perhaps, we should take a brief look at the pedagogy that it has, or has not, an impact on.

Traditionally, pedagogy and the cognitive sciences have followed separate paths, with occasional bridges materialising between them only when some major theoretical understanding in the psychology of learning has achieved acceptance in the province of teaching – and then usually after considerable delay. Recently, however, this situation is showing signs of improvement. The conception, for instance, of intelligence as being made up of a general factor accompanied by a host of specific ones which has been instrumental in the development of quantitative approaches to cognition is now being applied to pedagogy – witness the widespread introduction of tests to assess educational performance. More than this: understanding of the strong influence of the environment on learning, together with the findings on the importance of early learning, have accompanied the development of "active" and "participatory" pedagogical models targeted at the younger children, while appreciation of cognitive abilities as a mechanical response to stimuli (behaviourism) has found widespread application in drill-and-practice approaches to learning. More holistic models of cognitive development such as Piaget's have had a much harder time to penetrate either pedagogy or education.

More recent research on learning processes has certainly changed our picture of what is important in learning and how it can be supported. A main change (already discussed) is the shift of the research focus away from the learning products and back to the processes underneath. The current emphasis of cognition research is on the concept of learning as personal discovery, problem solving and information processing activities, rather than acquistion of specific skills or parcels of knowledge. Another important series of results confirms the importance of early learning habits for later performance.

The most immediate application of such research is in terms of a pedagogy centred on the learner, based on his/her previous learning habits and adapted to the ongoing learning processes via a continuous diagnosis of the learning performance. In other words, the new generation of pedagogical approaches is moving away from unitarian models of learning, towards a variety of mini-strategies, each adapted to a specific area of learning and specific learners.

It must be recognised that, in broad terms, pedagogues around the world have for long been reaching out towards such an objective. Their convictions did not stem, however, from any scientific understanding of learning processes; nevertheless they were firm about the pedagogical merit of individual attention, interactivity, interest and motivation, flexibility, personal exploration and discovery. The so-called "Socratic approach", currently adopted in computerised lessonware, is at least as ancient as Socrates' own maieutics. Similar principles have been the spur for all the major pedagogical developments of this century. Much the same principles guided the Italian M. Montessori at the turn of the century, the Swiss E. Claperède in the 20s, the Frenchman C. Freinet between the two World Wars and the Americans J. Dewey and B. Bloom in the 30s and 50s. In general, it would be hard to find in the last few decades any example of educational innovation which would not be inspired by one or the other of these historical founders of modern pedagogy.

Why, then, this revived interest in methods that have been tried successfully for so long? Why this aura of "newness" around pedagogical approaches that are, in fact, rather old? The answer must be because of progress in the cognitive sciences and because of the power of the new information technology. The research findings supply a "hard" basis to the "soft" (although highly respected) principles of pedagogy. The technology offers the instrumental opportunity to translate the specifics of the learning processes into pedagogical practice and enables, at virtually no extra cost, the kind of continuous evaluation that is central to known pedagogical models. So, it is the double capacity as "revealer" and "analyser" that makes information technology so valuable to the learning sciences; and its double role as "translator" and "evaluator" that makes it such a powerful aid to pedagogy.

Information Technology as a "Translator"

A number of taxonomies of computer software and courseware are based on the pedagogical approaches implicitly or explicitly built in, but they are all developed around the same indicator: the amount of control and independence of the learner *vis-a-vis* the computer. The categories usually range from the best known examples of Computer-Assisted Instruction (CAI), essentially drill-and-practice programs, to the most recent and sophisticated programs, where both the learner and the computer can play an active role. As already observed, the distribution of the programs produced so far over the various categories is highly uneven. The more sophisticated the pedagogical approach taken, the smaller is the number of programs publicly available, which confirms that recent advances in cognitive science are showing themselves only slowly in computer-based pedagogy.

The best known example of CAI – the computer-controlled – is based on a behaviouristic approach to learning. Typically, the program presents a frame containing a portion of the lesson material to be learned, asks a question and evaluates the student responses. It selects the next lesson frame on the basis of that response and, optionally, keeps a running cumulative score. In the words of one author, "this is the 'hospital' model of education, in which the student is regarded as a patient to be treated, or 'programmed', by the computer. 'Individualisation' in this case means only that one student may receive a different sequence of prestored frames than another. The program does not build a model of the student's knowledge and conceptual gaps and/or does not diagnose his/her difficulties along the way. Computer-controlled CAI applications are useful for teaching the acquisition of facts and for helping students memorise and consolidate factual knowledge. The two major varieties of such pedagogical uses of computers are drill-and-practice and tutorial programs. Most of the software and lessonware produced so far belongs to this category" (Feuerzeig *et al.*, 1981). Another example of computer-controlled approaches to learning are some pedagogical games such as word games designed to develop language skills.

At the other end of the spectrum one finds what can be called the student-controlled CAI. Here learning is viewed as an active process of investigation. The program exercises no control over the learning situation. The computer simply responds within the limitations of the program's repertoire to the student's commands. There is no prescription of what experiments the students should perform nor do the programs coach the student in any way. Software of this kind are rarer. Examples exist in topical learning areas such as mathematics, physics and statistics (Feuerzeig, 1981).

The so-called "expert programs", created in topical areas, can belong to either one of the above categories. They have been developed mostly in medicine and applied sciences. A similar grouping is that of "simulation programs", developed mostly for teaching physics, chemistry and biology. They use graphics to simulate experimental conditions. Another topical kind of program is one developed to teach foreign languages using computer-operated slide projectors and tape recorders, and graphics associated with sound patterns (Crossley, 1983).

Between these categories come the so-called mixed-initiatives systems. These come the closest to a Socratic approach to learning. Student and computer engage in a dialogue. The student can ask questions of the computer and the computer can respond and, in turn, ask its own questions. Usually the student works on a complex problem-solving task. The problem can have multiple solutions or no solution. The emphasis is on learning problem-solving procedures and strategies rather than on finding "the answer". Examples are developing proofs in logic or geometry, analysing unknown chemical substances, or finding faults in electronic circuits. (Feuerzeig, 1981). Other programs that could be classified as mixed-initiative ones are those developed for computerised homework, where in association with classroom activities, the computer can provide clues to overcome difficulties or revert to easier problems. Candidates for this category are also the programs that allow students to create their own computerised lessons. This seems to be among the types of program most enjoyed by students (Crossley, 1983).

Embedded in the above taxonomy is a classification of software in terms of pedagogical quality. Its general criterion is numbers: the fewer the software in a given category, the higher their quality can be expected to be. Le Corre and Schwartz have analysed the phenomenon in depth. They use economic and structural arguments to explain the problem and support the remedies they suggest.

The cost of creating high-quality courseware is still very high, they say, thus most currently available courseware is bound to be mediocre. The cure for this problem would require a substantial up-front investment in improved courseware-writing tools. It has taken a great deal of effort to realise that a good educational package can be something more than a skilfully programmed lesson on a computer, or interactive reading of a textbook. Educational games, simulation using animation, problem-solving, analysis of arguments emerging from artificial intelligence methods have opened up new horizons and have shown that certain teaching strategies require the use of a computer. One must expect production of really high-quality software to require TV studio-like teams incorporating many specialists – including subject area experts, talented teachers, graphic artists, software experts and educational psychologists.

As a consequence, CAI systems developers have not made effective use of all the technical possibilities of computers. In particular they have tended to avoid the exciting, fast-paced graphics environment central to the video game industry. Partly because the equipment available to CAI developers has been inferior, typical CAI systems do not integrate all the facilities that would create a favourable learning environment (colour, voice and music output, video images, split-screen and multi-screen displays, etc.). These facilities are not enough to create good teaching but it is noteworthy that, when properly used, they are of great help in getting the educational message across.

At present, courseware is implemented largely by amateurs, to wit middle-school teachers or university professors, who may be experts in some educational subject area but are new to the computer medium and generally unable to bring any special artistic concept of graphic ability to the challenging compositions that they undertake. Publishing firms are also becoming interested in the field and are groping for a definition of their role, but have not yet become active on any significant scale, besides which they are accustomed to function more as marketing agents for individual authors than as high-spending producers in the "Hollywood" style that CAI will demand. In a few cases, e.g. Queensland and South Australia, Belgium, Canada, Finland, France and the United Kingdom, some educational courseware is being produced by government bodies, actuated by medium-term considerations and able to make larger investments. Attention must be drawn to the particularly elaborate call for tenders by Ontario Province as part of an ambitious project. But this is still uncommon and in small volume. Only a fraction of the courseware presently available is produced by commercial enterprises able to focus the skills of larger and more expert teams. Moreover, the present efforts of commercial teams are sharply constrained by medium-term marketing considerations, for example the necessity of limiting courseware to whatever is able to run on the smallest and least expensive of today's home computers.

Besides financial investments, another strategy to increase the quality of educational software running on less powerful computer configurations is to invest in the production of "bright ideas". Exemplary courseware has been produced even with the limited set of software tools and hardware environments available at present. For example, courses in genetics and chemistry developed at the University of Illinois are excellent. Like many other appealing items in the present stock of courseware, these lesson sequences combine graphics with clever simulations to create lively "mini-worlds" which the student can explore in a variety of sensory modalities.

Several lessons explaining basic numerical concepts to very young children, which make excellent use of the touch-sensitivity of some of the terminals, are also noteworthy. Prof. A. Bork of the University of California at Irvine has exploited the combination of graphics and simulation to produce some particularly appealing material for introductory physics instruction. Far more elaborate simulations, some making use of highly-specialised computer-driven optical systems capable of duplicating the appearance of landing strips seen from various approach angles and in various lighting conditions, have been used to produce spectacular civilian and military pilot training systems.

Industrial firms have originated much training material in computer-driven videodisc formats. For example, at a more rudimentary level of capability, first-rate drill-and-practice material for elementary arithmetic has been produced by Patrick Suppes' organisation. But, in spite of these and numerous other bright spots, the general level of presently available courseware is low.

Information Technology as an "Evaluator"

As examples of the ways in which the NIT have been put to use to evaluate the pedagogical process, we can cite programs that have been developed to analyse the specific error patterns of learners (e.g. BUGGY). Others monitor the students' response patterns and provide feedback on acceptable alternative solutions to teachers who can then modify the classwork accordingly (e.g. ESOPE). Yet others compare students' performances with models of experts' performances and establish a diagnosis of the "missing skills" (e.g. WEST). Finally, equivalent evaluation techniques have been developed to monitor learning in novice teachers, when acquiring, for instance, classroom managements skills (Rees *et al.*, 1984). The list of strategies for dynamic evaluation can only grow longer in time.

Few would dispute the potential of the NIT to establish diagnosis on learning, to evaluate performance and keep track of students' progress on an ongoing basis, over a period of time, without disrupting the learning itself, as tests, or teachers, usually do. At least for the most sophisticated types of programs, pedagogical quality is insured by respecting a number of criteria including interactivity, recognition of errors and diagnosis of conceptual difficulties in the student, modulation of the learning session according to the competence and motivation of the learner, generation of dynamic feedback, flexibility of pathways towards solutions.

Much the same virtues are advocated for Computer-Based Learning by those who have used it. One of the most comprehensive sources of information on the views of the clients is a recent report by the French "Institut national de Recherche pédagogique" reviewing a ten-year experiment on computer-based classroom learning (INRP, 1981). Asked to indicate the most important characteristics of Computer-Based Learning, the students agreed on a number of issues. The computer computes fast, they said. It gives immediate feedback (used by most students for immediate self-correction, a type of self-imposed drill-and-practice). The computer forces the learner to think and clarify the approach to subject matters. "With the computer, it is the pupil who works, whereas in the classroom it is often the teacher". The possibility of individual tutoring is particularly appreciated: "There are 35 of us in the class, so the teacher can't tell each of us individually what to do. With the computer, it's as though there were one teacher for two pupils".

Personal autonomy with respect to the teacher is also appreciated: "We don't feel we have the teacher on our backs. The teacher is more in the background...", "the teacher isn't always on top of us correcting our mistakes". "We can give a wrong answer without looking stupid, which we can't in an ordinary lesson". "We're allowed to make a mistake". "The computer asks us a question and we answer, and if we get it wrong we can try something else". "The teacher is only there in case he's needed". Personal autonomy with respect to time is another point mentioned: "we have more time to think and we can slow down or go faster depending on what we can manage".

So far the analysis is promising: information technology can play a role in fostering understanding of the learning processes and in applying it in practices of pedagogical quality. The analysis is equally clear on the risks involved, on the "perverse" or just the "unexpected" effects possible on the way. Cognitive scientists and pedagogues are faced with a highly appealing and difficult task: how to bend the technology to support their work, how to maximise the advantages while keeping the disadvantages under control. The balance is difficult to strike, the challenge worth considering.

Chapter IV

THE IMPACT ON THE EDUCATION SYSTEM: TEACHERS, TEACHING AND CURRICULUM

The contributions that information technology can make to mass education was a matter of interest and discussion throughout the Conference. The lead-in was given by Mrs. Bette Stephenson in her opening address:

> The vast information storage capacity of the modern microcomputer makes possible (on a large scale) a generally unattained goal of educational reform for the past fifty years. The computer can evaluate the student's prior knowledge, leaping ahead or dropping back in the instructional sequence as required. Instructional sequences can be branched, following different pathways depending on the student's progress and report that progress to the teacher. At the same time, it is capable of identifying the points in the instructional sequences which cause the greatest difficulty. The pedagogical effectiveness of such programs will be limited not by the machines but by the insight and imagination of our educators.
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> It is this improvement in the productivity of learning that in my view has the greatest significance for the future role of the school. Let me hasten to note that increased productivity does not signal the replacement of teachers by machines. In our schools, we need all of the teachers, all of the human contact we can afford. Although we have tried very hard to improve the efficiency of learning we seem of late to have reached an outer limit with the resources and methods now available to us. In most educational systems, we accept the fact that the majority of our students – in practice – master only a fraction of the intended curriculum. And it is not because the teachers are poor or that they don't work hard and intelligently.
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> The new technology gives us an opportunity to move beyond this impasse, if we use it positively and creatively. Although we are still at the early infancy stage of development in educational computing, the best state-of-the-art lessonware and courseware can do superbly many of the routine tasks which too often occupy so much of the teacher's time and energy that very little is left for the stimulating, more creative and more professional aspects of teaching. In effect, we can automate many of those routine functions and automate them in ways which students find engaging, in ways which can be individualised, in ways that a teacher in charge of a class of 25 cannot possibly do, and with a patience that even a saint could not equal! I may be overly optimistic but at least potentially we are much closer to being able to achieve something like true mastery learning, in almost 100 per cent of the intended curriculum.
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> And as we become more proficient in the design of educational software, we can develop even more sophisticated learning aids, and as more powerful and versatile computers become more widely available, our students will become more proficient in the creative personal use of the computer. Through all of this they will be extending their conceptual grasp and accelerating their intellectual development.

Our purpose now is to look more closely into the hopes and concerns voiced in arguments such as these in the light of experience gained in the course of the project and of the Conference deliberations. Our objective will be to confront events with expectations, to assess whether and to what extent the potential claimed of the new technology towards the organisation and functioning of the institution of education is materialising or can materialise on the largest scale.

At first sight, the state of education in most countries does not look particularly receptive to change. When considering the ways in which learning is organised in the typical classroom of OECD Member countries, not much is found suggesting that it will be easy, or painless, to make room for the pedagogy and the practices carried by the NIT. Current practices do not allow much autonomy to the learner, nor much interactivity or personal exploration and discovery. A large-scale survey of US schools has revealed classroom situations that are common to other countries (Goodlad, 1983). "Teachers varied in the quality of their lecturing, for example, but 'teacher talk' was by far the dominant classroom activity. Teachers rarely encouraged student-to-student dialogue or provided opportunities for students to work collaboratively in small groups or to plan, set goals, determine alternative ways of achieving these goals", "the emphasis was on recall, not on problem solving or enquiry". "We received an overwhelming impression of students' passivity. Furthermore they apparently rather enjoyed the dominant activity of listening, which demands so little of them".

Besides the teacher-dominated instruction, very little time is left to the class to engage in other activities, either individually or in small groups. To continue with Goodlad: "At both elementary and secondary levels, approximately 75 per cent of class time is instructional, while most of the remaning time is spent on routine work such as preparation for instruction, role-taking and cleanup ... Nearly 70 per cent of total class time involves verbal interaction or 'talk' ... Approximately half of the verbal interaction time is devoted to teacher talk ... Less than a fifth of the time involves student talk ... Teachers, therefore 'out-talk' students by a ratio of nearly three to one ... Barely 5 per cent of instructional time is spent on direct questioning (of a student by a teacher) ... Less than 1 per cent of that time is devoted to open questions which call for more complex cognitive or affective responses ... Nearly 67 per cent of the elementary students and 75 per cent of the secondary students work as a total class. Less than 5 per cent are found working individually and less than 10 per cent are found working in small configurations." The author's conclusion is paradoxical: to the extent that talking requires the organisation of thought and can be an important avenue to learning, teachers were doing most of the learning.

Like other technologies in the past, the new information technology presents the education system with an alternative in that it qualifies as a vehicle to integrate some of the pedagogical principles that have been familiar to innovators for some time, but have only recently acquired authority through the results of cognitive research. The resulting pedagogical methodology is not, of course, exclusive to the NIT. Given time, resources and specialised manpower, a good deal of what is now being developed in the context of the technology could be carried out apart from it, by people working with ordinary educational tools. This has happened in the past and could happen again, but (and this is the crucial point) not everywhere in education. Modern pedagogy has entered the classroom mostly in individual innovative schools, where there is a tradition of children learning at their own pace, according to their own abilities and interests, within a flexible curriculum, under the personal guidance of their teachers.

Usually, the circumstances of such innovative education have been quite exceptional: outstanding teachers, adequate resources, a supportive community. These conditions are not easily reunited in the education system, where the absence of them is more the rule.

Nevertheless this is the point in the relationship between pedagogy and mass education where the NIT have most to offer. Their role is not so much to make a new pedagogy available to all pupils (the pedagogy proposed is not entirely new) as to offer a service of quality, based on sound pedagogical principles, in situations that are not exceptional to the system, at a cost which could be afforded by all. The question now is whether the historical obstacles preventing the large-scale introduction of modern pedagogy can be removed to make room for the new technologies, and whether the education system can then operate a shift from a pedagogy of convenience to a pedagogy of efficiency.

TEACHERS AND TEACHING

In view of the limited quantity and distribution of equipment in schools, by no means all teachers can be involved with the new technology and its impact on teaching and on the curriculum cannot but be fragmentary. In our review, we must do our best, therefore, with evidence that is itself fragmentary.

Quantitative estimates of teachers actually involved in the introduction of information technology in education are very scarce and, in many cases, misleading. The incidence of new NIT-orientated curricula, in terms of time and resources, is also uncharted. Virtually no quantitative data exists on alterations to established school schedules, new allocations of teachers and teacher time implied by technological changes. Very little evaluation has been done of the actual merits of the new technology for learning in ordinary educational situations.

There is no doubt, though, that teachers control a major gateway to change. Their attitudes and motivation, their personality and their training are important facilitators – or bottlenecks – in the process. The picture was put thus by Gilbert de Landsheere, General Rapporteur, at the Conference:

> The methods that teachers use are governed by beliefs and attitudes that have been deeply and unconsciously absorbed during their school career, which in some countries begins at the age of three in the case of more than 90 per cent of children and thus lasts at least 15 years up to the end of compulsory education. That is why, when they themselves become teachers, they tend to copy the teaching techniques that were used when they were at school and not the techniques advocated by more recent teaching theory.
>
> Before training anyone to use these new technologies or, more accurately, concurrently with this training, the underlying attitudes and habits of educational practice need to be thoroughly reformed. This will be a complex and costly operation and will only be achieved by working together with the teachers over a long period of time and by endeavouring to resolve jointly the problems that they have decided to tackle.

The question of the teachers' role, now and in the future, was pursued in greater depth by Rhys Gwyn in his report:

> It is clear that the insertion of the NIT into educational use will – or at least has the potential to – bring about changes in the ways in which learning can be organised; that is to say, in the ways in which teachers function. We cannot predict fully the likely nature of these changes, partly because they are in any case notoriously complex, but also because there have not been sufficient teachers and, most importantly of all, makers of educational policy, with sufficient appreciation of the potential of the NIT to enable suitable forms of training to be established. It is a key problem. There is a very real sense in which it would matter relatively little if technological advance were to halt over night

> (it is of course unthinkable that it should) since there is sufficient implicit in existing technology to keep educationalists occupied for the rest of the century. But the full educational advance cannot and will not be made until a sounder understanding has been established of the new kinds of learning that become possible, of which of these are desirable, of their implications for the role and the functions of the teacher, and of their further implications for teacher education and training.
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> There is an important point implicit in the wording of the last paragraph: it resides in the deliberate emphasis upon the word 'learning'. For, while it is clear that the focus is upon the teacher, teacher functions and teacher training, it is also essential to remember that the teacher is only a means to an end. The end is the education of the child. The danger of a focus upon the concept of the teacher is that it may engender the unquestioning assumption that, while minor modifications to the role may come about, the role itself will endure. A common belief is that this is, in fact, the case, and that teachers will continue to be needed for the education of children for a very long time. But it has at the same time to be recognised that some of the potential uses claimed for the NIT do call in question the teacher role itself, while others postulate a change in teacher functions so extensive as to demand a major re-evaluation of that role. The emphasis on the centrality of the learning, rather than the teaching process, will help to maintain these possibilities in focus.

While the importance of teacher training in the general area of the new information technology seems undisputed, there is less clarity as to the proper content and specific targeting of the programmes. One of the few studies of this question was conducted in 1984 by the College of Education of the University of Minnesota. According to this, the list of competences teachers ought to have includes "knowledge of basic computer components and operation", "knowledge of materials and projects related to computer education","knowledge of educational and personal uses of computer", "knowledge of individual differences as they relate to Computer-Assisted learning", "the ability to evaluate instructional software", "the ability to develop/manage an environment in which computers are available for teaching/learning", "knowledge of educational and societal implications of the 'information age'", "the ability to use authoring languages and to program".

The list looks comprehensive enough. It also looks impressive. The question to ask next is whether all teachers need to acquire all the abilities and knowledge thus identified. The three levels of involvement identified in the introduction to this review – "high-level specialists", "appliers" and "users" – could very well cover the alternative roles of teachers in the future. As with other professions, there is every reason to expect that those producing the new curricula (the high-level specialists) will be the least numerous; more will be applying existing courseware, and more still will be those just needing to use what is given.

Teachers as High-level Specialists

The issue of training a teacher as a high-level specialist, able to create courseware is, according to many experts, a complex one. Le Corre and Schwartz, in their report to the Conference, suggested why, twenty years ago, the teacher-author did not perform impressively well and why, now, the situation could improve.

> At the time, the first reaction of teachers was to prepare a program representing, simply and individually, what they themselves would say, with requirements they themselves laid down. But a student at a computer does not fit exactly into that situation, and the range of responses available was usually too limited (multiple-choice questions, words to complete, etc.). However, with progress over the last twenty years, and the advent of

sufficiently powerful microcomputers, open-response software can be produced with branching tailored to the pupil's needs and potential".

Using low-level authoring languages, it is possible now to construct teaching dialogues with conditional branching and limited response analysis. The authors can thus concentrate on the teaching problems and receive the appropriate training. In the case of self-instruction, group discussions are, in practice, necessary. Authoring languages will, in most cases, have prompt modes. Various guides, like those distributed by CONDUIT, give advice on the drafting of teaching material including supporting documents. A short-cycle training course should include these teaching techniques and provide some additional knowledge of computers: utilities, procedures, functions, connection of terminals and computers.

By using the functions of a fairly complete authoring language more complete courseware can be written without constraints as regards teaching strategies and without problems of programming. In the case of standard teaching strategies, a prompt mode can be used and avoids the problem of selecting implicit instructions (e.g. allow for blank spaces or not, upper case/lower case, limitations in the loops, etc.)

In the creation of original courseware, some parts cannot be dealt with using an authoring language. This is often the case with simulation, learning games or artificial intelligence where a special module has to be written in a computer language. The author or authors must be thoroughly familiar with it and be able to manipulate the graphic and animation capabilities of the computer. At this stage, it becomes useful to know something about the concepts of artificial intelligence. The level of training has to be equivalent to that of research. It is available in universities and institutes at undergraduate level culminating in a degree in computer science, telecommunications or education. The production of complex courseware, such as that used for training pilots, requires substantial audiovisual facilities, i.e. television studios, videodisc, etc., which are something like those needed for making a film or television programme. Training in these audiovisual techniques needs to include studying the different situations where the computer linkup offers new scope, e.g. audiovisual databanks, videodisc operation, Computer-Aided Design, computer animation, etc.

The training for teachers called to perform at such a high level of specialisation requires, in the opinion of Le Corre and Schwartz, no less than a long-cycle training course covering, for instance, a full year. In a short training course, it is not possible to develop the instruction on computers, since the teaching aspect has to take precedence, i.e. definition of the subject matter, how the microcomputer can help, definition of objectives, analysis of tasks, observation of user reactions, pre-test and post-test, choice of teaching strategy, choice of terminal, writing of supporting documents, tests, comprehension of texts, readability of program, student and teacher reaction, etc.

According to these authors, a long-cycle training course would be better, covering a full year, and divided into three roughly equal parts. The first would cover the data processing aspects: structure of computers, peripherals and data transmission, operating systems, knowledge of a number of languages (including BASIC and PASCAL), structure of data and methods of program design and authoring systems. Standard and specialised applications of computers should also be dealt with, i.e. databanks, text editors, Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), Computer-Aided Translation (CAT), etc. The second part would include teaching applications covering the contribution of computers to education, their different applications and the stages of designing, testing and validating courseware material. The education aspect of the training should cover teaching methods and educational psychology, i.e. learning, the cognitive processes, the objectives of education, the characteristics of students, the diagnosis of their errors or inability to understand, the presentation which is most suited to them or which they themselves might prefer.

Le Corre and Schwartz conclude that this part of the training should be rounded off by individual or preferably group work with an experienced team. Finally, such teachers should receive career training: work experience in different schools and in documentation and distribution centres in order to provide an insight into the difficulties encountered by teachers using computers in their work. The running of CAI centres or computer clubs in schools will be facilitated by the contacts built up during this kind of work experience. In addition, training needs to be provided on the operation of the hardware and light maintenance.

Teachers as Appliers

Defining functions and training needs in the middle of the range has been attempted by Rhys Gwyn, who after examining the information obtained from a number of countries, has concluded on the clear emergence of a middle-level specialist, an "NIT co-ordinator",for whom there is a growing demand in education. This person is expected to be identified as "resource person", knowledgeable about the NIT, to whom their colleagues can turn for informal advice; he or she is expected to take a lead, more formally, in school-based in-service training; be responsible for the management of NIT hardware and software resources and of technical support staff; contribute to software design and development; advise headteachers and school managements on acquisitions policy as well as on longer-term education development.

The phenomenon, says Gwyn, is interesting, and widespread. It is referred to in a case study for the CERI project by Jean Valérien dealing with developments in the Académie of Rennes: the "animateur" function is a recognised part of the strategy of dissemination in France. Valérien shows how those teachers who emerge from the one-year, intensive, courses of training in the NIT arranged within a given Académie are required to discharge a co-ordinating function within their own institution and to pass on their new-found skills to others; some, indeed, become full-time trainers. In France, the role of the NIT co-ordinator is pre-planned; a case study contributed by T.D. Pike to the United Kingdom background report, on the other hand, shows how this kind of role has often developed from the enthusiasm of an individual. Not that all United Kingdom development is pragmatic: W.R. Broderick in the same report shows how one English Local Authority planned for the creation of such a role. The case studies of Estes and of Hess and Miura also refer to the important contribution made by this new category of teacher in the United States, while the Dutch case studies of Carleer and Bijlstra draw attention to the concern felt at school Principal level about becoming over-dependent on the expertise of a small number of NIT-skilled staff.

There is here, identifiably, a new, albeit specialised, cluster of teacher functions to be discharged, and a great many teachers, in diverse settings, are carrying an extremely heavy burden in an attempt to respond to the challenge. Indeed, it is questionable if the whole phenomenon of NIT in education would have left its launching pad had it not been for the quite extraordinary enthusiasm the topic has generated among teachers. The demands are onerous. The "NIT co-ordinator" in a school must not only discharge all the functions just identified, but must also keep abreast of constant technological development. Merely to remain well informed in the United Kingdom, for instance, requires familiarity with at least eight monthly technical journals, as well as many new books, the publication rate of which far outstrips that for any of the traditional school subjects. Yet a further dimension of learning is added by the machines themselves. Familiarisation with the intricacies of a microcomputer such as the Acorn/BBC machine, for example, is in itself a demanding process. Nor are the microcomputers the only machines to be mastered; peripherals such as disk storage systems, printers, Videotex and Teletext adapters and network interfaces each have their own operating systems all of which have to be learned. Finally, to demonstrate software to colleagues, or to teach to students, requires considerable prior time spent in study and evaluation.

This is not a problem that is likely to go away. The preparatory training which is undergone by some teachers – for example, that supplied by the French long courses – does not obviate the necessity for constant self-updating. At present, there is no evidence of allowance being made for this need. A case study from one of the Scottish regions by C.F. MacLean specifically draws attention to the need to allow teachers discharging these new clusters of functions to have time for the necessary personal development. As matters stand, the demands of computer clubs, peer training and the writing of programs for both pupil use and the use of colleagues (for the motivation to demonstrate to others the values of the new technologies is high) leave time at a premium. Valérien's report also details the demands made on the time of "animateurs" – while acknowledging the impossibility of exact quantification.

The next point that must be made relates specifically to the new "NIT co-ordinator" teachers but is also significant for any teacher who comes into contact with the new technologies. It is that the learning demands imposed upon teachers are not merely those centered upon the technology. Onerous though this area is, there is an even greater learning challenge to be faced which is not technological but essentially pedagogical in nature.

This becomes clearer if we re-examine the catalogue just given of the new functions imposed upon the co-ordinator/teachers. Anne Liddell spelt it out in her case study. Peer training, for example, calls for a high degree of pedagogical understanding, to say nothing of associated skills in interpersonal relations and in sheer old-fashioned diplomacy, which is much called upon where colleagues (possibly of considerable seniority) are hostile to the new technologies. Nonetheless, peer training has a valuable contribution to make: the Dutch case study on the St-Odulphuslyceum (secondary school) refers to this as an accepted modality for staff development. However, difficulties do exist: resentment of the comparatively lavish resourcing currently available to the NIT in schools and colleges is often another complicating factor (T.D. Pike). Equally, many teachers are wary of a situation in which some of their pupils are known already to possess more expertise than they have (Hess and Miura).

Similarly, while it is clear that the design of good software presupposes an understanding of what the computer is capable of doing, what is often called into question is the teacher's ability to write-in sound learning experiences. This clearly is a pedagogical, not a technological, skill, and the fact that the teaching/learning medium is new makes an especial demand upon the NIT co-ordinator's capability in pedagogical analysis and design.

Teachers as Users

Rhys Gwyn has taken a particular look at the basic competences and knowledge demanded of the ordinary teachers, the users. Their functions lie in a three-stage pattern. The first relates to the technology of the machine. Two components are involved here: "basic machine competence" and "competence in management of the hardware resource". While these might appear at first sight to be relatively low-level functions (as, essentially, they are) they nonetheless represent a formidable addition to the range of competences hitherto acquired by teachers.

At the second stage, there are the functions that relate to software – in other words, to understanding what tasks the NIT are currently capable of undertaking. At present, these may be represented simply as "competence in the range of applications offered by the NIT". Nonetheless, this is in itself a very wide field, and the extent to which it broadens the range of teacher functions is, as we shall see, very considerable. Third, there are classroom-based functions, related to the translation of the potential of the technologies into pedagogic use. This, also, is an extensive and complex field, but for the purposes of outline only it may be identified as "competence in the pedagogic use of applications of the NIT".

It is important to emphasize that the key stage, at present, is the second: acquisition of an understanding of what the technologies are capable of doing. The first two components, related to the hardware itself, tend all too easily to become disproportionately important in both formal and informal training provisions. There are reasons why this should be so. Using a microcomputer – considered purely as machine – is, after all, considerably more complex than using, say, a slide projector or a tape recorder in the classroom; the fact of pupil use is in itself sufficient to present the teacher with a host of unforeseen problems. But the reasoning goes deeper. There was a phase in the evolution of the automobile when to be a driver one needed also to be a mechanic (or be able to employ a driver-mechanic); the same was true of the early aviators. Similarly, there has been a period in which the use of the computer has been very much the province of those able to master it as a machine – in other words, to program. This is reflected in the contents of many syllabuses dealing with what is termed, in the United Kingdom, Computer Studies, and also in the assumptions which many teachers bring with them to in-service training courses.

One of the most welcome of recent trends has been a discernible move away from this emphasis on the teacher as programmer in the direction of teacher as (informed) user. If this shift is to be maintained, it becomes important to see that all teachers understand the range of applications of which the technology is capable. It is competence in this area that stands at the interface between the technology and its educational use; once this is more broadly established the way will be much clearer to proceed with pedagogical exploration, since the appreciation of, and ability to use, applications is quite different from skill in programming. To return to our analogy, it represents the difference between the competent driver and the competent mechanic – and it is quite arguable that we are in more urgent need of improving skills as drivers than as mechanics.

"Basic machine competence" is vital to any teacher, requiring far more than the ability to switch a machine on and off, or even to load and save programs. The run-of-the-mill techniques of entering data, retrieving crashes, making backup copies, dealing with disk faults, obtaining printouts and screen dumps are all necessary to the teacher who wishes to be no more than a competent client, one who uses the resources of the new technologies without necessarily becoming involved in any developmental work. This addition to the standard range of competences must not be underestimated. There are far too many points at which the technology can "play up", and thereby ruin a carefully prepared lesson, for the matter to be taken lightly – especially in the view of the essentially interactive nature of the medium. It is often difficult enough for the teacher to deal with his or her own errors, but it is necessary also to be able to cope with those induced by the child. One answer to the problem (though at best partial) would be a considerable increase in provision of ancilliary staff (technicians) competent in computer hardware, but in present economic climates it would be unwise to bank on this. The position, then, is that there is a range of basic machine competences that must be acquired by all teacher users of the new technologies.

"Competence in management of the hardware resource" would provide an answer to one of the worries of ordinary teachers: the extent to which the extension of their competences depends on the amount of hardware available. The point is that, while fully-equipped computer classrooms are now coming more widely into being, they are still not commonplace.

Hamilton and Casserly, for example, in the United States background report, refer to an analysis of the hardware situation in schools associated with the Council of the Great City Schools (and hence not claimed to be wholly representative of the United States). This indicates an average ratio, at secondary level, of one computer (micro or terminal) to every 186 pupils, though ratios ranged from 1:40 to 1:473. At primary level, the average was 1:863, in the range 1:97 to 1:4 000!). Clearly, improving such ratios is a long-term and expensive task: a very crude notional calculation for the United Kingdom, based on projected expenditure for the City of Manchester over a five-year period, and aimed at putting twelve microcomputers into every City secondary school, would cost approximately £85 million. The implications for teachers are obvious, and the statistics illustrate perfectly why teachers who habitually use computers frequently find themselves carrying delicate and fragile equipment around school buildings and elsewhere. Thus we have the paradox of scarce resources being under-used: another United States survey (Center for Social Organisation of Schools, Johns Hopkins University, June 1983) quotes eleven and thirteen hours per week at elementary and secondary levels respectively as typical of the use made of school micros.

Yet, again typically, most pupils receive only a very limited amount of time at the keyboard each week: a school such as the Lamplighter School in Texas is decidedly atypical in its equipment resources, and Nolan Estes suggests that thirty to forty minutes is about average for the time a secondary pupil might spend at the keyboard, per week. This does not take into account, of course, access to privately-owned computers in the home. There exists, clearly, a major problem of resource management, and there enters a new teacher task: that of working out how best to utilise a form of learning which is heavily machine-based when the number of machines available is not adequate. In an ideal world, the problem would not exist, but it does, and represents a major additional burden upon the teacher.

While the first two functional stages are certainly demanding, they are nonetheless essentially machine-related. But what is true for business users of the new technologies is true also for education, namely that the hardware is of less intrinsic importance than the software which it runs. Thus it is only when we move away from machine-related issues and begin to examine the range of applications offered by software that we can truly begin to explore the educational potential of the NIT.

The full range of this potential is only beginning to emerge. Early developments were characterised by two emphases. One, upon uses in the field of mathematics, is understandable given the developmental history of the computer, but misleading insofar as it gives only a very limited picture of what the new technologies have to offer. This problem is doubly confounded by the fact that mathematics, sadly, is a subject area in which many teachers as well as pupils profess limitations and even antipathy. While there are strong, and bi-directional, links between mathematics and computer usage, there are, as we shall see, many more possibilities for educational development than in the field of mathematics alone. The second emphasis, upon relatively simple drill-and-practice programs, is even more unfortunate. It is also wryly ironic, in that the unprecendented but still limited powers of the microcomputer have tempted many teacher enthusiasts into producing such programs, when experts who have worked for many years in the field of Artificial Intelligence, using mainframe computers, realise just how far research and development have yet to go before we can produce programs which begin to match the sophistication the teacher brings to the instructional function (O'Shea and Self, 1983).

Teacher Training

Having clarified the competences needed it remains to decide when and how they could be acquired. At the moment, most of teacher training provisions in Member countries concern in-service more than pre-service training. This (and here we again paraphrase Rhys Gwyn) is entirely understandable since it is an accepted fact that new thinking can be injected into teaching more quickly via this route – where courses can be mounted at relatively short notice and can be brief and intensive – than via the necessarily longer pre-service route which produces, after all, the junior members of the profession. Nonetheless, there is evidence also from some countries of considerable development taking place at pre-service level; for instance in Valérien's report, from France, and in a contribution to the United Kingdom report by R. Hartley, Director of the Computer-Based Learning Unit of the University of Leeds. It is also relevant that in the United States two states now require all teachers to gain computer competence; these and another five states require pre-service training to incorporate computer classes. Many school boards, Nolan Estes reports, require proof of computer competence for high school graduation. In the State of California, moves to identify expected computer competences at each of grades K-12 are expected to have their impact on teacher accreditation requirements. Overall, however, Estes finds that training programmes are relatively narrowly conceived at in-service level.

Rhys Gwyn continues by pointing out that there are major problems to be tackled in this area if we are to have any hope of mounting, via teacher education, a worthwhile response to the challenge. The first of them is one of analysis, for the situation to be examined is essentially circular, with no obvious point of entry. The new technologies carry implications for all subject areas across the curriculum, and at both primary and secondary levels. Given that the number of teachers at these levels who can reasonably claim to have received undergraduate training in informatics is negligible, we face the need to train, as rapidly as possible, the entirety of the teaching profession to use the new technologies. Given, again, the rapid evolution of the whole NIT area, it is scarcely any exaggeration to say that the whole profession would need, by some means or another, to be placed in semi-permanent retraining. There are many reasons why it is wildly impracticable to think in these terms; not least, a lack of trained trainers, economic constraints, insufficiently clear agreement on the directions to be followed. The logistics of such an exercise, too, would be overwhelming. Yet this is, in fact, the fundamental task facing the various agencies of teacher in-service training, and its seriousness should not be ignored. So far, the most viable scheme to have emerged at national level is that of France. The MEP scheme in the United Kingdom also places a heavy emphasis on teacher training but, because of the country's decentralised system of education, it is not in a position itself to offer INSET schemes on the same scale.

As we have already said, there is a greater possibility of flexible responses to new developments at in-service level than at pre-service. In the latter area, courses are of longer duration and often subject to formal processes of approval and control which are less easy to change. There is, too, the difficulty of inserting new areas of learning into already crowded curricula. Maurice Edmundson in his case study enlarges upon this, remarking how difficult it has proved in the United Kingdom to insert into the very crowded one-year course of post-graduate teacher training anything approaching a sufficient initiation into the new technologies for all students – and this in an institution where colleagues are strongly supportive and hardware resources available. What is equally interesting is the marked increase in student demand, over some three or four years, for some element of computer literacy to be introduced into their courses. Elsewhere, too, the teacher training institutions are doing their best to meet the demand. The Netherlands background report, for instance, provides a detailed outline of course structures devised by Ubbo Emmius College (Groningen) to teach the new technologies to pre-service students and teachers in service, at secondary level. The ground covered ranges from basic understanding of machine architecture to study of the social implications of microcomputers. However, Nolan Estes' comments on pre-service teacher training in the United States bear out the observation that, although responses to the NIT have been introduced into curricula, the training itself has not been altered substantially. The technology has had to be integrated into existing course structures; methodology and delivery systems are not affected.

Hardware resources, of course, are not necessarily available to all teacher training institutions, and there are resourcing problems to be faced on a large scale in many countries. Nor is this a question of hardware alone; it is a commonplace of business use of the NIT to look first for software appropriate to needs, and to worry about the hardware later. The same situations cannot yet be said to apply in education, since the hardware is considerably more in evidence than is software which will truly stand up to educational scrutiny. Nonetheless, this too is beginning to emerge, and it places upon the budgets of teacher education institutions a heavy burden of purchasing in a period when this particular sector of the education system, in a number of countries, is particularly subject to cut-back.

But the major resource problem is the human one. The proportion of teacher trainers with Information Technology as their "subject" is even lower than for teachers at secondary level. In those countries that allow professional movement laterally across disciplines, this has proved to be the solution; as might be expected, it has often been mathematicians who have provided the input. In countries where the teaching of a discipline is relatively strictly linked to possession of an academic qualification – Germany is a case in point – a severe problem exists. Nor can the problem of human resources be ignored in a country traditionally as flexible in its attitudes to subject qualifications as the United Kingdom, since the flexibility in the system is balanced out by a relative standstill on recruitment into teacher training for almost a decade. The need to retrain the trainers, if they are in fact to be able to train their own subject-area students, is acute. For the United States, Nolan Estes sees the problem as one in which "the computing and other technology-based competencies needed by educators have not been specified and agreed by colleges, universities and public schools... Generally, the elementary and secondary schools are leading the colleges and universities in new information technology, particularly instructional applications".

One of the problems facing teacher education is that of knowing which direction to follow in the provision made for students at both pre- and in-service levels. In a highly dynamic area such as the NIT, those involved in teacher training find themselves of necessity attempting to keep abreast of a range of developments. And the breadth of this range must not be underestimated; it encompasses the latest in educational software, which needs to be examined and evaluated, trends in the field of business applications, from which the educational world has so much to learn, new languages which appear to offer valuable directions for teaching (COMAL, LOGO, micro-PROLOG...) new applications packages (word processing, spreadsheet...), indications of policy directions and also the latest information from the world of academic research (Artificial Intelligence, expert systems...). The list is daunting. What it calls for is an involvement on two fronts: professional development and research.

CURRICULUM

In discussing the state of the art in curriculum we will make a distinction between the computer as a tool, computer science (whether a separate or an integrated discipline) and computer literacy. In fact this distinction is far from being as conceptually justified as the many debates on the subject could lead one to believe. When looking at the actual provisions in education as well as some of the more advanced (laboratory) educational applications of information technology, it is not often that one finds a separate curricular identity being accorded to these three aspects. Their interrelationship gets all the more confused as the provisions move away from vocational towards general education objectives. Still, as most of the information available in the countries comes under one or the other of these three labels we will report it in the same terms.

Elementary and Middle Schools

Changes in school curriculum have been analysed by Peter Bollerslev and Nolan Estes through the numerous case studies contributed by participating countries to the CERI Project. According to them, the elementary and middle school curricula have generally been impacted by the new information technologies by the incorporation of two new technology-related facets: teaching with computers (Computer-Assisted Instruction), and teaching about computers (computer literacy, computer science, programming). The international case studies report wide variations in the extent to which elementary and middle schools use technology for these purposes, as well as in the level of student and subject matter targeted. Many of the schools and school districts are in the initial phases of planning or implementing the use of technology for instructional purposes. Nevertheless, Bollerslev and Estes found it possible to make some valid generalisations.

The most frequently reported use of technology at the elementary level (they found) was for Computer-Assisted Instruction in reading and mathematics. Generally, this takes the forms of drill-and-practice exercises, enrichment activities, and remedial activities. In the United States, very minimal use of technology is reported for problem-solving, simulations, or the development of reasoning skills. In the Denmark study, a focus is placed on problem-solving, which has been found to have a great pedagogical effect in terms of transfer to other subject areas. In the United Kingdom study, the computer has provided the students with a method for handling primary source data, which would not otherwise have been possible. The Australian study illustrates the successful application of Computer-Assisted Instruction to the area of handwriting. The procedure for teaching handwriting skills has been radically changed as a result of the introduction of the technological approach. Since the technology is used to present exercises, teachers have spent a greater proportion of the time in reviewing curriculum materials and deciding which materials suit individual students. In essence, the repetitive aspects involved in the traditional forms of teaching handwriting have been replaced by a computer presentation which offers significant advantages. It was found that changes in curriculum had taken place because teachers have started to use the technology as a classroom research tool in that they have begun to experiment with varying curriculum materials for different students. Thus, the technology has given teachers a powerful tool with which to plan appropriate curriculum strategies.

Teaching about computers is generally introduced at the upper elementary or middle school level. Some of the districts in the United States study defined "computer literacy" through the development of a list of objectives or skills that students are expected to master at a given level. In some cases, these objectives define a new "strand" of the curriculum parallel in structure to a language, arts or mathematics strand. In other cases, the objectives are added to an existing strand, such as that of mathematics or science, but not real integration has been reported. The Council of the Great City Schools reports that many large districts do not have a computer literacy course, *per se*, but rather infuse literacy throughout the curriculum as part of their Computer-Assisted Instruction plan. The Denmark study describes a mandated subject for grades 5-9 in which the students are taught about the positive and negative societal implications of the new technology as well as programming and information about the hardware.

Overall, the new information technologies have had only a moderate impact on the elementary and middle school curricula. Most elementary curricula have remained unchanged, with teachers using the computer as another teaching tool to support or supplement the regular programme of instruction. Computer Literacy courses may be introduced at the middle school level, but not in any interdisciplinary fashion. It is too early to be certain as to how the introduction of new technology is affecting the curriculum. From the experience to date we are just able to draw indications as to possible future developments. Some of the teachers questioned whether anything new was being done with the computer that had not been done before albeit in other ways.

Upper Secondary Schools

Continuing with our resumé of Bollerslev and Estes' analysis – the impact of technology on upper secondary curricula is most evident in the addition of computer science courses and other computer-related courses in mathematics, science, and vocational education (e.g. job training courses). The survey conducted by the U.S. Council of Great City Schools indicates that all the large districts but one offer computer science courses, averaging about seven different such courses per district. In general, these course offerings focus on programming skills or computer theory. One of the New Zealand case studies describes a secondary school that has implemented computer studies courses as an optional subject over a three-year sequence. A variety of topics are included, which are presented at more advanced levels of understanding, each successive year. One of the Dutch case studies describes a school for general secondary education in which computers are used for a computer science course, a test service system, and remedial teaching. The Belgian study describes the use of computers in three secondary technical schools for teaching vocational training in the areas of accountancy and book-keeping. The vast majority of the districts described in the United States study have added new computer-related courses at the secondary level. Many districts reported much greater impact on the secondary curricula than on the elementary level. In the United Kingdom, computing studies courses are offered in which students learn at least three different computer languages and work in close contact with local businesses on real projects. In addition, a special course on Microcomputer Applications is offered.

The impact of technology at the secondary level is most evident in the addition of new courses, less evident in the modification of existing courses, and minimally evident in terms of interdisciplinary involvement. The United States study indicates that the only modification of existing courses has occurred in the areas of mathematics, science, and vocational education. Other subject areas are relatively untouched by the new information technologies. An exception is reported in a New Zealand case study in which the introduction of microcomputers has caused an increased awareness among the staff and students about some of the social implications of the new technology. As a result, a 12-hour module on "computer awareness" has been added to the Social Studies curriculum.

Another notable exception is described in the United Kingdom case study on secondary education. Computer awareness has been introduced as an essential element in each of the major subject areas of the core curriculum (Mathematics, Science, European Studies/English, and Humanities). In addition, the use of information technology has been gradually developed in science for simulation and data capture, in technology for design and drafting, in music for practice and self-correction in the learning of chords and intervals, in English for the development of linguistics and logical problem-solving, and in remedial courses for children with learning difficulties. The United Kingdom secondary case study, the U.S. Congress Office of Technology Assessment Report, and New Zealand's case study N°2 cite the lack of high quality and appropriate software. In the United Kingdom study, teachers developed about 25 per cent of the software they use. The vocational training programme described in the Belgian study implies some interdisciplinary involvement in that other subjects such as business law, economics, and management have been integrated with the use of technology.

Higher Education

The introduction of the new information technology in higher education is equally uneven, with some departments and courses expanded and/or changed more than others. Such an irregular landscape presents, however, some typical patterns. The most conspicuous is to be found in professional education. Here, as Pamela Christoffel has pointed out, computer-related provisions have partaken of the generalised growth of colleges and universities in this sector.

In Japan, for example, the number of computer science departments grew from five in 1970 to 43 in national and private municipal universities by 1980. Computer science is now being taught in all the technological universities in Turkey, and all engineering students, as well as some from other disciplines, receive obligatory training in computer science.

In Ireland there were 29 specialised courses in the computer science area available at seven third-level colleges in 1981. That same year about 5 000 students took modules in computer science at Irish institutions as part of their overall training in other areas, mainly science, engineering and commerce. The University of Linkoping in Sweden has a special "Computer science and technology line" where computer science is the main part of the education – one of several lines leading to a "Master of engineering science". This programme is unique in Sweden.

Another good example of the rapid growth and restructuring of professional education is in Scotland where computing modules are included in Higher Diploma and degree courses wherever relevant (some voluntary, some not). Thus, report Scottish authorities, all engineering students would have a course in computing, and many science and business studies students would have similar courses. They also report that the numbers of students taking computing modules and full computing courses have increased rapidly in the last five years. The total intake has probably doubled in the last three years and the demand for places in degree courses (both in colleges and universities) is such that the entry qualifications are steadily rising. Indeed, in Scottish universities the entry qualifications for computing and for micro-electronics courses are starting to rival those of medicine and law.

In the United States where 90 per cent of all colleges and universities either have their own computers or access to others, all types of institutions, public and private, two-year and four-year, offer courses and degrees in computer science. Enrolments are growing due to demand from business and industry for such students.

EMERGING ISSUES AND PROBLEMS

Those who would have liked to see mass education already well engaged on the road to the technology will doubtless consider the position just described a disappointing one. Why are so few teachers trained? Why is so little of the curriculum affected by the technology? Why is so much of the new curriculum a mere add-on, and why is so little of the existing curriculum actually renovated? Some of the reasons at the core of current developments have already been discussed – ranging through (usually scarce) resources, (sometimes adverse) attitudes of all those concerned, and (still scarce) knowledge of the pedagogical merits of the technology.

A number of obstacles appear more clearly than others. The teachers' "territorial imperatives" set powerful boundaries to the realisation of the potential of the NIT as do their own levels of competence. Usually, teachers are careful to teach only their grade level and not to transgress on the next (Burnett *et al.*, 1983). They have also been observed to restrict students' learning to their own level of familiarity with the new technology-based learning systems (Crossley, 1983; Naymark, 1983).

Variables such as the organisation of the classroom have also been found to be crucial to success. The software available does not usually fit in with classroom work. Most products developed for classroom uses of micros allow profitable use by only one child at a time. For teachers to use effectively a device which is primarily geared for a single user, when they have one machine per 30 children, demands, at the minimum, a major planning effort (Becker, 1982). In the end, the technologies are forced to fit in with classroom practice rather than the reverse. Most of the software available is neither individualised nor adaptive. An entire class works on the same material at any given time and is expected to proceed through the course at the same rate (Feuerzeig, 1981).

Should the situation evolve without major qualitative changes, the schools of the future would resemble those pictured paradoxically by S. Papert, who feared that the system would just absorb the change, by using "new technologies to reinforce educational methods whose very existence is a reflection of the limitations of the precomputer period" (Papert, 1980). A French author echoes similar concerns, and emphasizes the conceptual and organisational difficulties inherent in the "quantum leap" forced on schools by the new information technologies: "The main obstacle ... is institutional resistance on the part of the school to any organisational change tending to displace the teacher's lecturing as the source of knowledge in favour of learning based on manipulating and experimenting. This is not just an ideological barrier, as all too often stated, because that fortress has already been well and truly breached. The difficulty is that noone is quite sure how to approach it, and there are very few people one can turn to for guidance. It is not just habits that have to be changed, but the whole organisation of work, time and premises that has to be rethought" (F. Robert, 1982).

On a longer-term perspective, the forecast could however be less pessimistic. In countries where the NIT have entered ordinary classrooms to an extent above average, where teachers and pupils have had more time and opportunity to use the microcomputer, the indications are that, in the long run, desirable qualitative changes could probably take place. The Center for Social Organization of Schools, Johns Hopkins University, is analysing the use of microcomputers in ordinary United States schools at the primary and secondary level (CSOS, 1983 and 1984). A first important result of this analysis is that the introduction of the microcomputers in schools generates a dynamic, rather than a static, configuration. As time goes on and as more equipment is available and more teachers are involved, the use of the microcomputer evolves. Such evolution – and this is the second most important result – follows a pattern which remains specific to the level of the school (primary as opposed to secondary), the number of teachers involved (one as opposed to several) and the involvement of school administrators. The typical primary school uses the microcomputer mostly for drill-and-practice and remedial work, with a shift towards computer programming and computer literacy as more equipment becomes available. The typical secondary school uses microcomputers mostly for computer programming.

Resource constraints seem to have a different impact on primary and secondary schools. In the former, usually underequipped as compared to the latter, the equipment available is more evenly distributed across the school population. More microcomputers means here more children with access to them. In secondary schools, access is strongly skewed in favour of "programmers" as opposed to "drillers". Furthermore, an increase in computers results in increased time per student, rather than increased students per machine. In both elementary and secondary schools, the shift of initiative and control from the single enthusiastic teacher to a group of teachers and to school administrators correlates with a more even distribution of user time and type of use of the microcomputers.

Basically, similar evidence emerges from other smaller-scale observations of Canadian (Logan, 1983) and French schools (Naymark, 1983), with the conclusion that "in general, the picture that emerges is one with a strong flavour of trial-and-error, with teacher practices changing as their experience with computers grows, as their students' experience grows, and as the teachers themselves grow older" (Logan, 1983).

In terms of learning processes, the observed dynamics seem to produce, in the opinion of teachers, an impact which is essentially social and motivational rather than cognitive. Teachers in the large-scale United States survey confirm some of the anecdotal evidence to which we have already referred – that micros have led to increased student enthusiasm for schooling; to students working more independently; to students helping one another and answering each other's questions; and to students being assigned to do work more appropriate to their achievement level. Other smaller-scale studies tend to confirm the teachers' perception of classroom changes. Regular use of computers in their classroom – they say – has caused their style of teaching to change from teacher-centred to student-centred. The presence of the "computer-expert" students in the classroom has had the effect on the teacher's perception of students in general, to a more positive view of their capabilities (Miller, 1982).

It is worth emphasizing once again what rests at the core of the current difficulties: the large-scale availability of enough quality software readily usable in a course form. Bollerslev and Estes have reported on studies from the United Kingdom and the United States pointing to a dangerous consequence of such scarcity for the curriculum. This shortage (they say) can lead to an undesirable effect on the curriculum: it can distort it. Activities are undertaken that fit the availability of particular software rather than meeting needs. Yves Le Corre and Jacob Schwartz spell out the problem at some length. To start with (they say) courseware catalogues are more difficult to compile than catalogues of textbooks or audiovisual material. Catalogues of school textbooks describe them, state for what category of students they are intended and reproduce the table of contents together with several pages of text. These catalogues can be used to select a textbook on a given subject for a particular grade. Catalogues of scientific films are already much more difficult to compile and use – it is not easy to gauge whether a particular film will in fact be interesting, of the right standard and capable of holding the classes' attention, and to know whether it is self-contained or whether the teacher needs to prepare a suitable introduction. Courseware catalogues are even more difficult to compile. Perhaps one answer would be to use the CODEVTEL classification (not originally intended for CAI) developed by the ITU (International Telecommunications Union) in Geneva and approved by Member States for training their postal and telecommunications staff, amended and amplified to include the details required by the teacher *or* student, e.g. subject matter, aims, standard, target audience, potential uses, strategies, interactivity, etc. It would be desirable to follow some standard model for these specifications.

Information on courseware quality should also be more readily available than it is. The customer needs to be protected against misleading advertising. The State of Florida (Senate Bill Section 283-25) insists on a data collection and analysis test before a courseware package may be put on the market. A consumer association evaluates courseware by means of the

EPIE (Education Projects Information Exchange) and publishes its findings in an information letter (Microgram).

We expect the rapid diffusion of computer equipment to schools and, especially, homes to bring increasing masses of courseware onto the educational market. As this happens, the role of agencies able to provide schools and individuals with informed judgements as to the quality of these many offerings will grow. We have discussed in Chapter II some of the strategies of development already emerging in this area. Some assessments on quality are, for instance, already being provided by public authorities and by nationwide organisations of educational computer users like EDUCOM in the United States. Systematic strengthening of organisations of this kind seems desirable, as does the development of international links between various regional and national courseware diffusion and assessment bodies.

The function of software reviewers writing in the technical press is growing in importance, e.g. the *New York Times* now runs a weekly column entitled "Personal Computing" which regularly reviews not only instructional programs, but also word-processing packages, financial planning aids such as VISICALC, data-based systems for personal computers, etc., commenting on their ease of use and general quality. Consumer-oriented computing magazines like *BYTE* and *Personal Computing* publish increasingly voluminous material of this same type. Informal user comments on software systems also circulate actively and very rapidly through various electronic "bulletin boards" established within major computer networks such as ARPANET.

The Allenbach company publishes "Software Reports" and provides assessments and guidance on choice. These assessments are compiled after consulting teachers, parents and students, and processing their replies on a computer. This material, prepared by authors and distributors, should include a technical specification for the user indicating the subject (level, knowledge required) and also the hardware (peripherals, support operating system) together with a "quality" record dealing with teaching strategy, presentation and follow-up. A simplified representation of the package flow chart for the teacher is highly desirable. These specifications are not the same as the validation records produced from users' experiments.

Shopping for courseware is also a thorny issue. The best way of picking a book is to browse through it, glancing rapidly at a number of pages and stopping whenever something catches the eye or attracts the attention. This is hardly possible in the case of courseware. A few typical extracts from the instructional dialogue and a flowchart describing the teaching strategy provide useful but insufficient information. Preferably, therefore, courseware should be accompanied by descriptive literature designed either for teachers or for students.

In Great Britain, the CEDAR Project (Computers in Education as a Resource) has prepared a videotape containing key video sequences from a hundred or so preselected courseware packages. CEDAR circulates various information on English-language courseware and sends it to the fourteen MEP (Microelectronics Education Programme) Regional Centres, where it can be consulted. In the United States CONDUIT produced a magazine called *PIPELINE* until 1983, and now issues catalogues by subject or computer language. Some packages can be described in a one or two page abstract, with photographs of illustrations and graphics on the display screen.

The best way of assessing a courseware package is, of course, to try it out, but its manifold conditional branchings and the way in which these are decided may not always be spotted even after several runs on a terminal. One needs to be able to read clearly the corresponding instructions (on the listing or in an accompanying document). This will be simplified if the courseware is written in an authoring language or using a system designed to be easily understood. Users can inspect the courseware packages prepared by the various companies as well as some of those designed for specific microcomputers. This can be done through the manufacturers themselves or their agents in the big distribution centres. Courseware packages can also be examined in the clubs that are springing up in increasing numbers to promote computer applications. Periodic exhibitions, and in time probably also permanent exhibitions, i.e. computer museums, are well worth organising since they make it possible for school officials and individual consumers to gain personal knowledge of the advantages and shortcomings of various courseware packages through comparative inspection of many such systems.

According to one of the most advanced public agencies on educational applications of the new information technology, the consortium of United States universities CONDUIT, the following teaching strategies are already defined for prospective authors of educational software: drill and practice; computer-directed dialogue; student-directed dialogue; data analysis; problem-solving; and simulation and model-building.

As progress is made in both hardware and software production methodologies, other teaching approaches will also, no doubt, become possible. The issue will remain however of how to translate the advances in educational software and courseware in actual changes in the teaching style of the ordinary teacher in the ordinary classroom. The negative side of the coin – the many individual school teachers who, even in those countries relatively advanced in their uses of the NIT, remain unaffected by the new developments – has been stressed by Rhys Gwyn, while Nolan Estes reports bluntly that "the average classroom teacher is not teaching in a new or different way as a result of the technology". The reasons can be diverse: in many cases, there is suspicion or downright hostility, the basis of which may be anything from personal antipathy to technology *per se* to a distrust of educational consequences of the NIT. Often, this distrust reaches back to experience of programmed learning experiments, which is one of the more unfortunate associations conjured up by the vision of computer technology in education.

Four reasons for teaching style remaining unchanged were given by teachers in Brittany schools interviewed by Jean Valérien. After using computers for two years their main problem was still the lack of overall pedagogical design defining the role and function of the NIT with respect to the established curriculum. The scarcity of software readily available and the difficulty of creating their own software were second worse items on the list. Third ranking were the lack of specialised personnel, such as an overall coordinator (a teacher freed from most other commitments) and a series of "advisors by each specific subject" (teachers with some hours freed). Last but not least was the lack of a nearby support centre and the inadequacy of the training offered to teachers.

Pamela Christoffel has noted that the situation in higher education is not dissimilar. In particular, studies of faculty attitudes towards the use of the NIT in America, have revealed consistent problems caused by faculty resistance to the use of telecommunications for instructional purposes (Lewis, 1983). Some were found who resist any sort of change, some objected specifically to certain aspects of the NIT (it's impersonal, it diverts resources needed elsewhere, it threatens my job), others simply felt uncomfortable because they were unfamiliar with the technology. Interestingly, this survey identified a number of strategies that have been used effectively in American colleges and universities to help overcome such resistance. These include: providing for active oversight by departmental faculty; encouraging participation of prominent faculty in the project; utilising full-time rather than part-time faculty as much as possible; using the NIT in the least complicated and least obtrusive way; targeting use of the technology to save time for faculty members; and offering an effective orientation programme to participating faculty.

Yet, despite the many difficulties, the interest and motivation among teachers keeps growing. As familiarity with the possibilities of the new information technology develops, as apprehension decreases, an increasing number of teachers come to appreciate the merits of the new teaching tool for curriculum in general as well as for specialised subjects. In particular, they come to realise that computers can offer more than a helping hand to a teacher. The general consensus is that the use of computers in teaching requires more organisation, more advanced planning and significantly more preparation time than would be required to give typical classes. This seems to be true of schools as well as of colleges and universities, where the obligation to analyse the new teaching materials, to find how best to include them in the established curriculum, has forced many teachers to improve themselves generally, to rediscover their subject matter and the way to teach it. Awaiting a better understanding of the impact of the technology on learning processes and educational efficiency, this personal upgrading can certainly be seen as an immediate and positive outcome of the change.

Chapter V

THE IMPACT ON THE EDUCATION SYSTEM: BUDGETS, STRUCTURES AND CLIENTS

Most of the debates around the introduction of information technology in mass education dwell on the more immediate aspects of the problem: those of teachers and of the curriculum. The others have so far remained unobtrusive in both policy and practice. Yet, as theories and goodwill continue to materialise into programmes and investments, these other factors assume increasing importance. Their names are familiar enough: financial resources, administrative and employment structures, equipment and physical facilities and, of course, the clients. This chapter is on their role in determining whether and to what extent information technology can be introduced in education to good ends.

BUDGETS

In Chapter II it was shown how many OECD Member countries have stated their political will to introduce information technology in education and have made some resources available for it. It was also pointed out, however, how few are the countries where governments have taken long-term commitments – the only commensurate to the task – in terms of their responsibilities as direct or indirect providers of guidance and means. As we concluded, one of the reasons behind this reluctance is undoubtedly the insufficiency of information to justify a firm decision. Costing is one of the areas where this lack of data is particularly apparent.

Costs

Jean-Claude Eicher, in his report to the Conference, seeks for reasons why evaluations of costs are so scarce in numbers and difficult to compare. A common handicap (he observes) is their reference units, which vary across estimates. An example are two recent United States estimates, one indicating a minimum of $100 000 for the design and production of a one-semester course, a cost which would reach $150 000 if interactive videodiscs were used, the other indicating a cost of $15 000 per course unit. In the hypothesis that a teacher would need 100 course units a year, one would end up with an estimated cost of no less than $750 000 per semester. A French estimate leads to different figures still. Here the estimate is for the cost of one hour of Computer-Assisted Instruction of between FF 50,000 and FF 200,000. If a semester course is assumed to represent 60-100 hours of instruction, its price would range between FF 3 million to FF 20 million, that is of between $300 000 and $2 million.

If estimates of present costs are difficult to pin down to any degree of precision, likely future costs are even harder to assess. In the absence of a clear cut model approach to the estimate, Eicher has tried to clarify, at least, its components. Costs for designing and producing the message (he suggests) should be distinguished from costs of transmission and reception. The first is a fixed cost in the sense that it remains the same, regardless of the number of people receiving the message. The cost of transmission depends on the mode of transmission. If it is by an electromagnetic system (telephone line, radio or television broadcast), the cost is proportional to the time taken for the transmission, but does not vary according to the size of the audience. Reception involves devices (television screen, computer memory, tape recorder, videorecorder, etc.) that can serve only a limited number of people. The cost therefore increases with the size of the audience, but stepwise and not proportionally. The overall cost of a technology-based system thus increases with the number of pupils, although less than proportionally. At any rate the cost per pupil tends to fall.

As we are dealing with education, this list of cost items needs to include others. A major, and particularly elusive, one relates to the supply of the service of education. This cost depends, among other things, on the time taken for the message delivered to be really assimilated. New technologies have an impact on the time taken to transmit knowledge. In the traditional system, the duration of the different educational programmes is generally laid down for all establishments by regulations. The time for transmitting a given educational message is thus fixed in advance on the basis of experience of the efficiency of the traditional method of teaching through direct contact between an instructor and a group of pupils. The introduction of methods based on new technologies may enable this time to be reduced if, as claimed by the supporters of such systems, the student is able to assimilate the material more rapidly and requires shorter contact time with the teacher. In this case the economist is not interested in the annual cost per pupil – a traditional factor in educational cost estimates – but rather in the cost of transmitting a program. If it is desired to compare NIT-based programmes (provided that they are considered to take the same time to assimilate) the best unit of measurement is the pupil-hour. If it is desired to compare an NIT-based with a traditional system the most suitable unit is the cost of the programme per pupil. A recent estimate, for instance, tags on $120 a year per child for 10-minute daily drill-and-practice sessions (Levin and Meister, 1984).

Another important item to consider is, of course, opportunity costs. Eicher recalls that education economists have often pointed out that a substantial share of the cost of studies from the standpoint of the individual is foregone earnings. This is particularly true in the case of courses for adults when they are held during normal working hours. It has in fact been calculated that in a "traditional" cycle this could account for over 95 per cent of the total cost. To the extent that the use of new technologies may on the one hand enable the total training period to be considerably reduced and on the other, thanks to its flexibility, enable the training to be organised mainly outside working hours, there should be a very marked reduction in the total cost of the training cycle. However, the second factor may very well merely bring about a shift of cost from the employer to the employee, if the traditional cycle was at the employer's expense and the employee cannot persuade him to maintain this arrangement. As regards basic schooling on the other hand, it is unlikely that the large-scale introduction of NIT in schools will reduce the duration of educational cycles. But if the effect of the current technological revolution on working time and job supplied is considered, it may be assumed that on the one hand the foregone earnings of school-leavers will be reduced because they are more employable and on the other that the new organisation will enable vocational training to be obtained at the same time as a formal educational qualification which, again, should facilitate subsequent insertion in the labour market.

There may be several possible effects on the different payers. The public education system at present dominates in a majority of countries and is financed to a very large extent through government sources. Financing the technical equipment required by the new system may bring about a partial shift of the budgetary burden to three other payer groups. In countries where financing is centralised it can already be seen that governments are tending to encourage local authorities to contribute to the purchase of equipment for schools within their areas. The use of microcomputers and video recorders by pupils encourages the private purchase of such machines by parents and later on by young adults who recognised the value of them during their studies, so that private manufacturers are generally prepared to supply educational establishments at a reduced price. This practice is at present common in most Western industrialised countries. When such equipment is used in the context of distance learning, the cost is usually borne by the "pupil".

It is thus possible that in the future part of the financial burden of education will gradually shift from governments to other groups, and in particular to households. This covert fashion of modifying the responsibilities of the State raises a number of problems. In order to make an accurate evaluation of the economic costs entailed in the large-scale use of new information technologies and calculate the total cost of education organised in this way, it is essential to have reliable data presented in a standardized way. Even if financial flows only are considered, it is essential, for instance, to calculate the budgetary cost per pupil of a clearly defined course or programme, compare and monitor over a period the cost of different items of equipment valued at constant prices, break down the total cost of technical equipment according to the phase of the knowledge transmission process, identify the share of the total cost imputed to each payer. These conditions are far from fulfilled at present, so that it is hazardous to try to draw general conclusions. It is nevertheless possible to present a partial and approximate picture of the situation and (with due caution) indicate probable future trends on the basis of the available information.

The production phase. The phase of producing the "educational message" can theoretically be broken down into two stages, the development of a program and its reproduction on a storage medium, generally for use with a computer. In practice it is difficult to dissociate the two stages because the constraints imposed by the medium determine not only the form but also, at least to some extent, the content of the message.

The costs of producing educational software are mainly wage costs because it usually requires the participation of a considerable number of people with different skills. A common approach is that an author is responsible for the design and for writing accompanying texts, an education expert puts the work into appropriate form, a programmer codes the material according to the instructions of the first two, a graphics expert is responsible for graphics, layout and presentation, and lastly a marketing expert studies the potential market and the adaptation of the product to it. The time spent by the first two people (or groups) can be evaluated fairly accurately, but this is not true of the others, as everything depends on the general design of the program. Similarly, wages vary with the supply and demand situation. It can be assumed that programmers' wages will be high because they are at present scarce on the market. At the reproduction stage it is necessary to distinguish between the cost of copying discs or tapes, that of printing the documents, texts and instructions and that of preparing a model packing and reproducing it. The cost varies with the length of the documents and the number of copies required.

The transmission phase is that in which the educational message travels from where it was produced to where it is received. Evaluating the cost here is even harder than in the production phase because it varies widely according to the type of transmission, which in turn depends on the technology used and its level of development. Here, a distinction can be made between the transmission of a computer program on the one hand and that of audiovisual documents on the other. In both cases two extreme solutions are conceivable. If the computer program and accompanying instructions have to be transmitted from a central computer to a terminal via a telephone line, the cost depends on the time of transmission and can be very high. If it is desired that the program be truly interactive (i.e. that the pupil will be able to communicate with the machine in real time) it is necessary first to occupy a telephone line during the whole duration of the "lesson" and second to pay at the highest rate because teaching usually takes place during normal working hours.

The estimates range from about $1 300 per hour for a teleconference with ten participants scattered over the five continents to about $15 for the VIDINET system in the Netherlands and $6 to $12 for the PLATO system. Future trends will depend on telecommunications costs which are not likely to fall in the near future but could drop substantially in the longer term, especially if, as may be expected, preferential rates are granted for education. If, on the other hand, the program can be run locally from a disc, the transmission cost is limited to that of sending the disc and is thus negligible when divided by the number of students. The same is true for the transmission of audiovisual documents. If these have to be broadcast the cost is that of using the transmitter for the duration of the lesson. A Dutch study puts this at $1 340 per hour. If the program has been recorded on videodisc, the transmission cost is again negligible except in the case of a single student, but even in this latter case is still relatively low.

The reception phase is that in which the message is decoded and presented to the pupil. The cost is mainly that of the equipment. Modern education systems using new information technologies are based on the computer. At the present stage two types of organisation coexist. First, a minicomputer with terminals and second, microcomputers each serving a group of pupils and possibly being able to communicate with one another. This distinction is likely to become irrelevant in the near future because of constant improvements in microcomputers which can already perform the functions of minis. We shall therefore only consider cost associated with the micros.

This is the field in which the data are most plentiful, most reliable and most consistent. According to the type of hardware, the cost ranges from a minimum of $300 to a maximum of $6 000, with an average price for a machine with the generally accepted minimum level of performance costing between $1 000 and $2 000. It is generally considered that this cost, which has halved every two years since such equipment first appeared, will continue to do so for at least another few years. Certain authors even expect a cost of $100 in 1990 (Reddy, undated). More detailed studies, such as that by Jacob Schwartz (Schwartz, undated) put the 1990 price at $300, but this is because they consider that the production cost has to be multiplied by at least three to obtain the selling price.

An analysis of the different components making up the price of a microcomputer, however, shows that these forecasts may be over-optimistic. The price can in fact be broken down into three roughly equal parts. Technical manufacturing costs plus the manufacturers profit. The integrated circuits (central processor and memory) probably account for less than 10 per cent of this item, while the disc storage accounts for 30 per cent, assembly 10-15 per cent and ancillary equipment (power supply, chassis and housing, keyboard) 20-30 per cent. As labour accounts for a substantial share of the cost of these last components and opportunities for technical improvement seem more limited than is the case with integrated circuits, the conclusion must be that the scope for further cost reductions diminishes as the relative share of integrated circuits falls. Development costs in the broad sense (R&D, marketing and promotion) plus overheads offer even less prospects for reduction. With the expansion of the market and increased competition between producers, marketing costs, including the retailer's profit, may fall a little, but probably not by much. It is nevertheless possible that for sales promotion reasons this cost may be low or zero for education establishments.

There are thus grounds to believe that the scope for further reductions in microcomputer prices is being exhausted and prices are close to levelling off. This view is supported by another observation. Price trend forecasts are based on a given type of equipment and marketing organisation. The fact is, however, that when a new, more powerful model is launched on the market the earlier one is soon withdrawn from sale. The trend is thus not so much towards a reduction in the price of equipment with more or less stable performance, but more in the direction of significantly improved performance at a more or less constant price. An improved cost/effectiveness ratio is thus much more likely that an abortive reduction in cost.

The hardware does not consist of the central processor only: other major components must come into the calculations. The present cost of fast memory, for example, is estimated at $1 000 per megabyte and is expected to fall considerably by 1990, but it is also considered desirable that capacity should be increased to eight megabytes; this would keep the cost at about $2 000 while multiplying capacity by four and thus permitting very high quality graphic reproduction and considerably simplified programming.

Prices per unit capacity mass storage (slow memory), which enables a great quantity of information to be stored and used as required, are likely to fall substantially, but this will probably result in a dramatic increase in capacity for slightly lower cost. Retrieval costs at present vary according to type of storage (e.g. tape cassette or floppy disc). The use of a floppy disc unit is at present estimated at about $1 000 and that of a much improved version at $500 by 1990. The tape cassette, cheaper than the floppy disc, is likely to drop out of use. Display screens are currently estimated at $400 to $600 apiece. Their price is not expected to fall much by 1990. Other hardware, often accompanying the "core" computer, are audio-output devices, especially of language emitted by the machine, interfaces, printers, etc. No significant price falls are expected in this area. Jacob Schwartz puts the cost of a standard facility at $550 by 1990.

After it has been purchased all this hardware will require maintenance and repair. The maintenance cost for "traditional" equipment (computers, language laboratories) is already high. As regards the different components of the new integrated systems, it seems that maintenance will continue to be an important cost item. According to a French source (CEFI, 1983), maintenance costs already exceed the cost of hardware depreciation and are likely to increase, at least relatively, in the future. These costs could be significantly reduced if manufacturers were willing to alter equipment design so that servicing is reduced to tasks of low technical content that could be carried out by the user (changing cards or modules). Such a development appears unlikely, however, because of the vested interests of repairers on the one hand and manufacturers on the other, the latter preferring to be able to offer cheaper equipment in the hope that users will not hesitate to replace it in the case of breakdown.

Impact on School Budgets

It is important to underline the complexity and the size of the cost of introducing information technology in education. This is to alert not only decision-makers called to make large amounts of resources available countrywide, but also any single local education authority and headmaster planning to invest in the area. Analysts are now alerting the general educational public not to underestimate the financial burden implied in the exercise (e.g. Levin and Meister, 1984; Murray, 1985). Many educators seem to assume that the purchase price of computers represents the principal cost involved. The result is that many schools buy computers that remain underutilised or even unused due to inadequate provisions for collateral expenses. These have been found at times to amount to as much as three times the hardware purchase costs. Lack of resources to train personel, to ensure maintenance or

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secure facilities in which to house the computers are common ills in a number of schools, second only to the "computer budget" eating away good shares of the school resources ordinarily earmarked for time-honoured items such as pencils, paper or books.

Peter Bollerslev and Nolan Estes have identified the trend in some of their conclusions from the 25 United States case studies. According to them, policy changes are most evident in the area of financial allocations. The implementation of technology is expensive, and districts have employed a wide variety of strategies to meet the costs of this endeavour. Even in districts that are reducing staff as a budget measure, resources are being found to buy computer hardware and software. Many districts are directing state and federal funds, particularly those targeted for special populations, to acquire computers. Some are using state textbook money for the technology effort. Others are redirecting funds allocated for library books, media equipment, and basic supplies to the purchase of computer equipment.

This whole area of costing is new on the agenda for priority attention, yet its importance is already undisputable. Practice is showing that the issue of adequate resources for technology in education carries more stakes than one. Failing to acknowledge the situation is already generating the danger that the schools we know will be traded before time for schools that don't yet exist – the result being an educational vacuum.

STRUCTURES

Next to resources, factors that are proving central to the creation of good conditions for progress are those related to existing structures, especially of partnership, of administration and employment, and of equipment and physical facilities.

Partnership

The programmes and practices most successful in introducing information technology in education rest often on some form of partnership – within education as well as outside. A common situation is to find an all-teacher body taking the initiative, often on behalf of schools from one or more education authorities. This, for instance, was the case with a Japanese experiment in the city of Musashino. Here the Musashino City Educational Technology Research Committee, which consists of representatives from 13 elementary schools and six junior high schools, worked in close cooperation with teacher groups in each school to develop and implement microcomputer software for courses in Japanese, social studies, mathematics, science and English. Not unsurprisingly, the experiment used more resources than budgeted for. The objective would not have been met without most teachers volunteering to work overtime or use their free time to develop the software required without financial compensation. The software was then used in the class at appropriate times and ratios depending on the users.

A mixed school-university partnership approach, found less commonly than the former in a number of Member countries, is at the basis of another Japanese experiment. At Takezono Higashi elementary school information technology entered the classroom by way of co-operation between the Science Information Processing Center of Tsukuba University and the school staff, financed through the science research funds of the Ministry of Education. A Tsukuba University research group was in charge of the design of the system, supervised creation of the learning program (hardware and software) and the analysis. The school teachers were reponsible of developing the learning program (courseware) and instruction.

In other instances the private sector also is involved. Bollerslev and Estes, reviewing the United States case studies, have stressed how technological businesses in particular have been providing school districts with expertise, equipment, and financial assistance for technology. One district's governing board has a policy to match funds given by any outside source for technology. Other districts are working in conjunction with computer companies for the development of software to meet the district's needs. Several computer companies offer teacher training as part of a computer purchase.

According to Pamela Christoffel the involvement of the private sector in higher education in the United States is even more sizeable. High-tech industry-sponsored research centres are sprouting at colleges and universities. Equipment donated by companies is being tested and evaluated on campus. Institutions are busy developing high-tech training programmes for employees of business, to be delivered either at the institution or at the work site. Professional continuing education programmes are expanding. Faculty are increasingly hired as industry consultants.

Given the size and nature of the impact on the institution, Pamela Christoffel goes as far as asking some basic questions on its survival in its present form.

> Surely the old vision of the "groves of academe" far removed from the world of work is fading. Probably this is a positive development, a wise response to charges of unreasonable remoteness from reality that have been levelled at institutions in the past. Clearly the changes are being hastened by economic necessity. Higher education is an expensive enterprise, and there are finite limits to the abilities of students to pay. Research priorities demand costly equipment, and in few areas are the costs as high as in the study and use of NIT. Pressures (sometimes political, sometimes ethical) to provide community service push institutions into collaboration with local industry, as well as desires on the part of educators to provide real-world experiences for students.
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> And yet, there is a sense among some viewing the scene that the idea can be carried too far. Nowhere is this more a possibility than in the area of the NIT. It is easy today to visit colleges where the new technology research center is funded by a co-operative effort of a number of companies, the microcomputers in use by students are all donated or provided at discount by the equipment manufacturer, and the computer research underway is being conducted by faculty under a government military contract. The question arises: who has control here?
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> Such institutions stoutly proclaim their independence, of course, defending their industrial and governmental ties while preserving their intellectual freedom. And in most cases, the college or university is, in fact, uncompromised by such relationships. But the trends for increased collaboration in the future seem clear. So more and more institutions may find it necessary to review their position *vis-a-vis* business and industry, if they wish to preserve some measure of academic separation. The issue could be an important one at some institutions in the years ahead.

Administration and Employment

More closely identifiable with structural changes are the instances where new ad hoc agencies have been created and new employment profiles defined in education. Chapter II touches on the emergence of such ad hoc structures as part of specific strategies to implement policies or, more simply, particular *ad hoc* programmes. They are supposed to act as either support or production structures to ensure one or more functions such as to advise, train, develop or diffuse software, control its quality. Usually, the lifetime of these structures reflects the expected duration of the intervention and, importantly, of its financing.

Whether entirely new or only a redefinition of existing institutions, these structures correspond usually to a restructuring – frequently an expansion – of the corresponding sectors in the educational labour market. In the United States, for instance, most school districts have hired at least one and usually more new central office administrators to plan and co-ordinate the implemenation of technology in the instructional and/or management area of the system. This model is, however, not followed everywhere in the country. Bollerslev and Estes point out that other United States school districts prefer to utilise all levels of staff in the planning and implementation efforts, rather than to designate specialists for one role. Some small districts have added new technology-related responsibilities to the assignment of existing staff members, rather than hiring new staff. In plain words, the introduction of the new information technology in education has made no teacher redundant, at least so far. On the contrary, it has opened to some of them new career possibilities, and has created new employment possibilities in the sector.

A particularly telling example of both partnership and infrastructures developed as a response to the educational challenge from the new information technology is the British Microelectronic Education Programme (MEP) which we have already outlined in the chapter on Policies. Here, in the light of Lariccia and Megarry's report, we can give it closer attention. MEP is a government-funded programme which aims "to help schools prepare children for life in a society in which devices and systems based on microelectronics are commonplace and pervasive." It was announced in March 1980 with a budget of £8 million to spend over 1981-1984 and a remit to cover schools in England, Wales and Northern Ireland (Scotland is covered by a separate programme). MEP funding has been extended to bring the average funding per year since its creation to £4 million. For 1985-86, the budget is around £5 million per year. One of the aims of the programme has always been to decentralise control as soon as feasible. From the very start, MEP's whole approach has therefore been to work through Regional Information Centres (RICs) in partnership with groupings of local education authorities. MEP is due to end in March 1986. It will be replaced by a new structure, the Microelectronics Support Unit, which will run for five years, with a budget of £2.2 million in the first year. Decentralisation is continuing and the Local Education Authorities will take on new responsibilities, especially in the field of regional teacher training for ordinary schools.

In order to maximise the impact of funding which, although major, has to be applied to a school population approaching 10 million, MEP has pursued a policy of working through a number of other agencies: commercial software publishers, companies like British Petroleum (BP), International Business Machines (IBM), Standard Telephones and Cables (STC) and public organisations like the British Broadcasting Corporation and the Open University. The success of this policy is illustrated both by the quantity of resources it has sponsored – print, audiovisual, software, firmware and hardware – and by their quality.

MEP was planned for a Britain in which microcomputers were just beginning to spread in secondary schools and were virtually unknown in primary schools. During 1981-1984 various 50 per cent subsidy schemes were offered by the Department of Industry (now the Department of Trade and Industry) to stimulate the purchase of British micros and peripherals. These rapidly transformed the picture, especially for primary education. This enormously increased the pressure on MEP resources and led to the setting-up of an MEP National Primary Project in 1983. Furthermore, although MEP's remit did not include post-school education, demand has been such that the Department of Education and Science's Further Education Unit circulated an annotated directory of suitable MEP material in 1984.

In addition, MEP has undoubtedly influenced what is available on the domestic market: pressures on educationally aspirant parents are cleverly exploited by private advertisers. For instance, various battery-operated devices sold as toys on the domestic market have acquired educational respectability as a direct result of MEP-funded curriculum development projects and associated books.

Both within the formal education sector and outside it, then, MEP has been under constant pressure to expand its role and services from the very beginning. In spite of this, it gave serious thought to working out a strategy for maximising its impact and resisted the demands from various quarters that it should produce early results at all costs.

By mid-1983 the patient negotiation and preparatory work was beginning to pay off, as the first MEP Resources Catalogue demonstrated. In addition to a wide range of MEP-sponsored software and hardware was an extensive list of audiovisual resources: BBC radio programmes, tape/slide programmes on telesoftware in education and modular control, 20 videotapes and various classroom case studies on audiotape. The second edition in spring 1984 testifies to further progress and diversification.

Equipment and Physical Facilities

In most Member countries implementation of policies and programmes rests heavily on the nature and amount of hardware found on the premises as well as on the organisation of the relevant physical facilities. Given the relative scarcity of the first until recently, the second is only just emerging as an issue of its own, deserving some serious consideration.

On the equipment front, the current flow into the schools tends to be characterised by a narrow selection in terms of technology and a large one in terms of corresponding hardware. The material purchased in the larger numbers belongs to the family of computers. Other information technologies, such as telecommunications or optic fibres and cable technology are much less represented in both schools and universities, although the trend is stronger in the former than in the latter. The work stations usually found in educational establishments include micro or minicomputers, display screens, disk drivers, and printers. At times the configuration is linked to data bank networks, link-ups with video components such as videodiscs being rarer. Hardware configurations for distance education – satellite, cable telecommunication – are being introduced in some Member countries. In the majority of them, however, such equipment remains marginal to current policies and investments in education.

The hardware entering education in less formal ways tends to reflect a similar trend. Public and "grassroot" developments thus combine to enhance the same technological bias in education. To the extent that "computer power" sets boundaries to what can be achieved in terms of pedagogy, the selection of this particular type of technology introduces an important bias in the possible array of large-scale utilisations of the NIT in education. The type of computers found most often in schools are among the least powerful of the family that allows the more sophisticated pedagogical approaches. Their pedagogical applications are therefore also limited. The latest generations of micro and minicomputers, offering more "computer power" for the same price, can eventually offset the drawback in hardware. It remains to be seen if, when and how education can develop equipment policies and practices resourceful enough and flexible enough to increase its own "pedagogical power" accordingly.

In figures, the above considerations mean that there are still too few computers per school and too little time for students to spend with them. By January 1983, in all categories of United States secondary schools, a majority had at least one microcomputer, about 60 per cent had two or more, only 40 per cent had five or more. At the same epoch, the majority of primary schools did not have any microcomputer, only 46 per cent of them had one or more. Elementary schools then had a ratio of 100-200 pupils per computer, with an average access time per pupil of about 15 minutes per week. The median student/computer ratio in junior high schools was 181:1, the ratio went down to 88:1 for the best equipped secondary levels and the combination junior/senior highs. This means that the median of secondary school students using micros in a week ranged from 10 to 20 per cent, with a median of about twelve hours of use per week per student user. As for the teachers in about half of the schools with micros, only one or two teachers at most were found to be regular users (CSOS, 1983 and 1984). In Canada by the end of 1983, there was approximately 1 microcomputer for every 250 pupils (Crossley, 1983).

Since 1983, the introduction of NIT has evolved in the most advanced countries. For example the *Wall Street Journal* has undertaken a survey of computers in schools which concludes, in April 1985, that there are more than one million computers in United States public schools. In the United Kingdom (England) secondary schools now have an average of nine micros each or an average of one micro per 95 secondary pupils. Primary schools have an average of 1.2 micros per school – about one per 150 pupils. Almost all special schools have at least one micro. By early 1984, in Denmark, every secondary school had at least eight microcomputers, with a ratio of one computer for every 40 students. In primary schools, the computer/pupil ratio was much lower, at about one computer for every 125 pupils. In Luxembourg, all secondary schools are equipped with from 8 to 16 micros, connected to a local network. In France, by the end of 1985, 160 000 micros will be available for 11 million students, about one per 70 students – 33 000 schools will be equipped with one micro, 8 000 others with six to eight micros.

The common situation in most other countries is of a very uneven distribution of hardware, with some schools being equipped more than others depending on the school, and especially on the socio-economics of its location. The ratio of computers to pupils remains in general rather discouraging. A much more even – and far better – equipment level is found in most countries in specific educational lines: technical, commercial and professional education. This is true of post-compulsory education up to colleges and university. Austria, with its 1984 ratio of a workstation for every two pupils in commercial schools, has one of the highest equipment levels so far in a given educational line.

Such varying amounts of hardware has been lodged differently in schools. In some – fewer – cases a computer laboratory has been accommodated in the school building. In others computers have been installed in ordinary classrooms alongside other resources. Yet elsewhere, computers have been confined to existing specialised places such as the school library, the media centres and, in the case of higher education, private homes. The adoption of one or the other solution has had – obviously – different consequences on costs and management. What is perhaps less obvious is the emerging correlation between location of hardware and type of user as well as of use.

Pamela Christoffel has pointed out how the availability of hardware at work as well as at home is spurring academics to conduct more ambitious and sophisticated research work and to communicate with one another more frequently through electronic networks. A major United States survey of school uses of microcomputers has found, on the other hand, that location correlates with mixed benefits (CSOS, 1984). The conclusions drawn from observing 1 082 microcomputer-using schools, public and non-public, are worth mentioning *in extenso.*

Keeping microcomputers solely in classrooms (says the study) has largely negative consequences: fewer teachers use them, their range of use is narrower in primary schools (more drill-and-practice and less programming instruction), with smaller amounts of access time provided for pupils. The positive side of this is a more balanced representation of both below-average and above-average students in secondary schools. Putting computers in a laboratory situation, in contrast, has generally positive consequences (more use and more diversity of use), except for equity. Neither pattern, though, is related to respondent judgement regarding the academic or social and organisational consequences of having computers in school. Locating computers in libraries has a mixed impact. It may improve equity in elementary schools and increase use by teachers and students in secondary schools, but not much consequence appears to follow in terms of learning or improving social and organisational outcomes. Rotating microcomputers from room to room is generally positive for secondary schools and improves equity and access at elementary schools, but at the expenses of computer-using students getting an insufficient amount of computer time to accomplish much learning. Dispersing microcomputers among several locations at any one time appears to have only negative consequences for elementary schools, but has the benefit for secondary schools of increasing access to larger groups and for a broader range of activities. It would of course be unwise to generalise from these few studies as to the impact of location and physical facilities on learning benefits. Yet the data are impressive enough to suggest that these variables should be taken into account when designing how information technology should enter education.

Distance Learning

The power of information technology to operate on structures is giving special visibility and a potentially higher status to a relatively minor sector of our purview – distance education. Distance education has usually served those who were excluded from mainstream education, because they were too few to justify the existence of a local school, physically unable to attend a school, too old to enroll, or too busy earning a living. Even now, the integration of technology can alter this picture, perhaps beyond recognition.

Eicher, in his report to the Conference, points out that, compared with traditional education, distance education has always been characterised by a different distribution of costs and comparable internal efficiency. To the extent that its constituency remains small and its technology expensive, the economic advantages of the model are also limited. Currently, however, the availability of new and less costly ways of communicating and interacting might turn the distance education approach into a viable alternative to traditional service delivery mechanisms.

This type of education (Eicher continues) is characterised by high fixed costs and low variable costs. Most design, production and transmission costs are fixed, i.e. they are independent of the number of pupils. Reception costs are, to a large extent, variable, depending on the communication medium used. A major economic implication of this delivery mechanism is to tie its cost-effectiveness to the size of its constituency and to the kind of communication channel: the larger the number of people served and the lower the cost of the technology, the more competitive the formula as compared to traditional education.

A number of OECD countries are currently experimenting with the distance education idea. Some of the projects are developed on the university model. In Germany at the *Fernuniversität*, in Finland, in Norway through the *Norsk fjernundervisning*, in Canada, in Australia at Deakin University, in the United States, in Japan with its forthcoming Broadcast University of the Air and in the Netherlands where the new Open University is expected to start this year – all these universities use a variety of NIT to reach students (CRE, 1983). Many of these students are adults, working or homebound who would not otherwise be able to participate in higher education.

The *Fernuniversität* in Hagen, Germany opened in 1975 and enrols some 23 000 students, both full-time and half-time. Like all the others in Germany, it is a state university and is made up of faculties in Educational and Social Sciences, Economics and Business Administration, Mathematics and Computer Science, Law and Electrical Engineering. The course and examination structure corresponds to that of the conventional universities. The predominant teaching medium remains printed or written materials, but audio cassettes and televised courses are also used. In regional study centres students can also use specially-developed recordings and video tapes, and the university has recently begun a videotex experiment (Peters, 1983).

A parallel in Australia is Deakin University in Victoria, which serves on-campus students as a regional university as well as some 3 500 off-campus students. To serve the latter, Deakin uses microcomputers, telephones and satellites in various innovative ways (Northcott, 1983). Teleconferencing by telephone is used as a means to ensure tutorial service for groups discussions and (by satellite) to provide interaction between staff and students. Other services include on-line access to the library catalogue, electronic mail, electronic course material and special support service with modified tape recorders for disabled people.

In other countries there are examples of mixed models of distance education. In British Columbia, for instance, provisions have been developed based on the use of telecommunications networks as a joint venture of government, universities, community colleges and provincial institutes. In the United States, to mention yet another approach, the Council of the Great City Schools reports that the majority of city schools now have, or plan to have, cable capacity. In addition, about half of these districts use electronic mail, several have or expect to have videodiscs, and a few are experimenting with robotics.

At times, distance education is used to train teachers. This is the objective of a particularly successful United Kingdom project run by the Open University. The *Micros in Schools* Project has a £1 million budget, around half of which has been borrowed against future sales and half has been provided by the Microelectronics Education Programme. The Project is to produce five packs: Awareness, Educational Software, Micros in Action in the Classroom, Microelectronics and Microcomputers. The first three all emphasize educational software; their purpose is to make the teacher an intelligent consumer, aware of what is available and capable of making judgements about its suitability. The latter two packs include DESMOND, a battery-powered electronics kit, and incorporate extensive practical work. Around 75 per cent of the material is general, 25 per cent machine-specific.

It is not difficult to recognise in distance education one of the most promising areas of development. Its administrative and manpower structures as well as modes of financing are flexible enough to adapt to a variety of targets and needs. It remains to be seen whether its mandate, possibly expanded, could cover the much more complex role and function of the larger system of education, or just remain an alternative system, better suited to some learning and some learners, old enough or autonomous enough to be able to forego some of the more social aspects of classroom life.

THE CLIENTS

At the receiving end, where the pupils stand, most of the developments discussed in this report have only an indirect, albeit an essential bearing. Whether the hardware is of national or foreign manufacture is not of much interest for the learner, provided the performance is correct. The fact that the software has been written by teachers or by experts of informatics, that it has been bought by the education authorities or given free by the manufacturers, is equally non-relevant for the learning process, provided, of course, that its educational quality meets the standards. The particular curricular status granted to computer science (whether a separate discipline or an integrated subject) does not perhaps matter provided the pupil in the course of his or her educational career has been given access to that body of computer-related knowledge needed to function in society and, in particular, in the labour market.

What matters most to the young is the effective access to the new educational goods and the presence, at his or her side, of a competent tutor. This is the angle from which the investment in human and material resources made at the policy and implementation level becomes visible to the school's beneficiaries, their families and the community at large. These are the parameters along which the evaluation will be made (perhaps erroneously) by the general public. The background information presented to the CERI Conference shows how uneven this "visibility" still is in Member countries: access to the new information technology is not granted evenly across the education system. The compounded outcome of the various strategies whereby the NIT are being introduced in education is that important cleavages exist in their impact on the school population. The news that the response of education to the new information technology is marked by a degree of inequality towards its clients was no surprise for the participants at the Conference, most of whom already felt that it is inequality rather than the opposite that characterises the majority of our schools and universities.

As to this admitted "inequality of treatment", it would be naive to expect that a single innovation, such as the introduction of the new information technologies in the school, could alone dismantle what a century of educational policies and practices has largely created. Yet the awareness of the limitations of the cure should not deny its possible merit. Otherwise, left to its own dynamics, the introduction of the NIT in education could very well increase the differences, as some of the evidence shows already.

Age

The most common forms of cleavage in the school population in terms of their access to and use of the technology, are defined along the lines of age, thus of educational level, of socio-economic background and of gender. The age cleavage is the most commonly found in Member countries. It separates the primary from the secondary education pupils. It is built mainly on differences in equipment and software. Secondary and vocational education receives better equipment, is equipped faster, and with a larger variety of courseware. At times these differences have emerged spontaneously in all those countries where, as we have seen, the purchase of equipment and the production of software rest essentially on local resources and motivation. At other times, the differences are the result of explicit pecking orders established by policy between educational levels. This is the case in countries implementing the "top to bottom" or the "vocational" approach in equipment strategies. In yet other cases, the situation is the outcome of specific decisions being taken at the policy level excluding primary education pupils on the grounds of inadequate cognitive development – the younger pupils are said to lack the mature cognitive skills required to master, say, the concepts of computer science. This is the case, notably, in countries such as Sweden, where the now completed DIS project has been instrumental in the non-introduction of computer-related subjects (actually, programming) in the primary curriculum.

Primary education, which the learning sciences indicate unmistakably as the priority educational target in terms of cognitive development, are left systematically behind in most countries. Furthermore, most of the investment in basic education is going to remedial education in its latest years. One wonders at the possible savings in material and human resources if only the educational interventions were better targeted at the very beginning of the cycle. Rhys Gwyn has made the strongest warning against the aggregated neglect of primary education which, he says, entails unacceptable costs in terms of lost benefits for the pupils as well as for pedagogy.

This is a highly important and, to some extent, controversial point. In a number of countries very little, or very little that stems from official policy, has been done to meet the challenge of the NIT at primary level – indeed it is by no means universally agreed if, as a matter of principle, the NIT should be seen as having anything to offer at this level. Nevertheless, while the entry of the NIT into primary education in, for example, the United Kingdom and the United States is much more recent than at secondary level, more than enough has been achieved already to make it abundantly clear that the new technologies have in fact a great deal to offer primary pupils and teachers.

It is not merely the much publicised claims of LOGO (Abelson and diSessa, 1981; Bossuet, 1982; Papert, 1980; B. Schwartz, 1981) that substantiate this point, though, to anyone who has worked on LOGO with primary children it is evident that this language has a major contribution to make to the young child's learning. But work at the primary level, certainly in United Kingdom schools, extends far beyond LOGO. Extensive data base programs, word-processing, adventure games and simulations – as well as the ubiquitous drill-and-practice – have all been tried and tested at primary level, showing that the NIT certainly have a role here. It is a role that could be denied by policy decision, though it is difficult to see how primary schools anywhere can withstand the onslaught of the home computer: to take no heed of the "educational" software now finding its way on to the home computer market would be shortsighted in the extreme. A failure on the part of the primary school to incorporate the use of the new technologies into its everyday practice could do nothing but accelerate the very trend postulated by some as a serious threat to the role of the teacher – namely a *de facto* privatisation of education by unchecked commercial production of "learning software" designed for use outside the school – in other words the home.

This is a defensive argument for the adoption of the new technologies by the primary school. There is also a more positive and creative one. Primary schools, most of which are cross-disciplinary, open and creative in their approaches and free from the constraints of external examination, provide ideal settings in which to explore the educational potential of the NIT. This is confirmed by laboratory research and by teachers working in ordinary schools. The UK case study shows, for example, a positive outcome in terms of improvement in the pedagogical skills of staff. Estes, of the University of Texas and Hess and Miura, at Stanford, also point clearly to the microcomputer as an educational force to be reckoned with at primary level.

But it is not only the micro that is coming into the picture. Carleer and Bijlstra (Twente University) report on an ethnically-mixed primary school in the Netherlands that uses 17 terminals from a minicomputer. The project there, being carried out in collaboration with the University of Leiden, is concerned with the evaluation of pupil progress using Computer-Managed Instruction (CMI) in Dutch language and arithmetic. This has been extended to Dutch language programmes for foreign-born pupils. The project has provided many positive insights into learning processes, the individualisation of learning, and its management. The evidence cannot be dismissed easily: the questions concerning the insertion of the NIT into primary education are not "whether", but "how quickly?" and "how effectively?"

Class

To say that some groups of pupils, if not all, have access to the NIT does not necessarily mean that they are served up to their needs. We have already reported the number of schools in the Member countries equipped with microcomputers. It is relevant now to translate these figures into average equipment per educational level. At the primary level, the typical school in Queensland, Australia, had no more than 2.3 microcomputers in late 1982. At secondary level the figure went up to 3.1. In Japan, in 1983, the average number of microcomputers per school did not exceed 1.4 at the primary level, 2.2 in the lower secondary and 4.1 in the upper secondary institutions. A typical school in Scotland has only one or two micros, while in England and Wales it has five to nine. In Switzerland "equipped" secondary schools have an average of 5.5 microcomputers, with an average of about one working post every 13 pupils, in the last year of upper secondary schools. It is yet to be seen if the official objectives of eight (France) or 16 (Luxembourg) microcomputers per school would bring the figures to the level advocated by some German teachers, that is one workstation for every two to three pupils. In some of the vocational schools, such as the Austrian commercial schools, this quantitative objective has already been reached.

In colleges and universities the aggregated figures are not much better. Few universities can claim the same levels of equipment as the United States universities where the students have access to as many microcomputers as they need, wherever they might be: the equipment is located throughout the dormitories as well as the classrooms.

With the passing of time, the above figures have no doubt improved. What remains to be seen is whether the pattern of growth will attenuate the geographical inequalities that exist at present. Although exceptions exist, the trend here at the moment is highly skewed in favour of "rich" schools. The schools that could be defined as better off in traditional educational and socio-economic terms are also better off with respect to the technology.

The schools that could be defined as poor on former grounds tend to remain poor in technological terms. Unless specific public interventions are planned, as in some Member countries, the gap between rich and poor will grow only wider. The problem is all the more urgent to solve as the inequalities in schools risk being increasingly aggravated by inequality in the homes, where the pattern of diffusion of the new technology is devastatingly class-specific.

Noting the emergence of the same class bias in formal as well as informal programmes, Lariccia and Megarry have no doubt that possession of a home computer system breeds confidence in computer users which confers upon them a massive advantage in acquiring competence. The greatest thing to fear in learning about NIT is fear itself. The opportunity to experiment and make mistakes in the privacy of one's own home is a great confidence-builder, and it follows that children from computer-owning homes are at an "unfair" advantage. (It is interesting that several large firms and education authorities wanting to spread computer literacy among executives and teachers have recognised this by a deliberate policy of home loans.)

How expensive – and how unfair – is this advantage? In Britain it is estimated that 20 per cent of homes have at least one computer in mid-1985. If you already have a television and a cassette recorder, serious home computing may begin at around £130 (the price of a new 48 K Sinclair Spectrum) or less; this is around the national average weekly wage. If you already have a telephone, access to interactive videotex (Prestel) costs another £100 for the modem (excluding running costs). Making effective use of all this is another story. Serious programming demands a printer, faster external memory than a cassette recorder provides, a monitor so that the computer user is not dependent on time-sharing the family television, a permanent set-up with the furniture and space to accommodate it, not to mention software, paper and blank tapes and disks. Word-processing demands a proper moving-key keyboard and may invite a better-quality printer. From £1 000 to £1 500 would be more realistic for a working personal computer system at 1984 United Kingdom prices. Thus computers may be cheap but computing is still expensive.

Even so, many British families will spend more than £1 000 on the annual family holiday, and sometimes much more on a new car. The word "expensive" says as much about the purchaser's attitude as it does about price. Middle-class families are more likely to see a home computer as an investment in the future, the 1980s equivalent of a children's encyclopaedia, and perhaps also to imagine that they will learn to program it "some day". Advertisers have not been slow to exploit middle-class anxiety that their children may be "left behind". Some of the micros bought in this spirit are never used, the parents having seriously underestimated their children's interest or the time and energy required to produce worthwhile results. Nevertheless, there is no doubt that children whose parents are able and willing to afford a home computer are at a significant advantage.

The extent to which higher socio-economic groups tend to predominate in NIT initiatives is in many ways a paradox. After all, the alienation of working-class children from formal education is often explained in terms of an academic curriculum deriving historically from upper-class culture and a teaching force that embodies middle-class values, attitudes and language habits. By contrast, micros employ the archetypal symbol of mass culture: the television. Computer games often resemble electronic fruit machines and space invaders. Because computers involve people in practical activity, they offer ways of making abstract concepts like syntax, logical deductions and geometry into concrete events like the failure of a program, a screenful of garbage or the movement of a Turtle. Thus, the argument runs, the working-class child ought to feel more at home with computers than with books, and the relentless logic of the computer should combat any tendency among middle-class teachers to confuse refined speech or elaborate verbosity with ability. Yet the case studies clearly demonstrate that microcomputers are not releasing working-class talent on the expected scale. Possibly it is still too soon to expect results; probably the greater likelihood that middle-class children have access to a home computer is still a factor. But perhaps part of the answer lies again in the image of NIT, a feeling that "this is not for us".

Gender

Throughout the body of information gathered in Member countries, a recurring theme was the underparticipation of females of all ages in technology-related programmes. In schools, inequality in terms of the technology grows along the familiar line dividing the sciences from the humanities.

Given the uncertain (at best) correlation found between proficiency in computing and "maths" abilities, one wonders as to the pedagogical justificaton of the educational decision. A number of studies in the United States show how the perceived association with maths and sciences, together with the content of most software available, appealing to boys rather than to girls, are "scaring away" girls in much larger numbers than boys (Beyers, 1983). The fact that the levels of schooling where the technologies are introduced most are those where the sex biases are already deeply entrenched, namely the secondary schools, makes the forecast for technological sex biases in the population only more gloomy.

In the homes, the situation is not far better. In an article on a large-scale United Kingdom survey of 6 to 7 and 9 to 10-year-old pupils conducted in early 1985 (after Christmas book of computer sales) Anita Straker reported that "Twice as many boys than girls have access to a microcomputer at home. Nearly twice as many will have a calculator. Far more boys than girls have a digital watch, and the group of children least likely to have any of these are girls who are single children or only have sisters" (Straker, 1985). It is interesting to note that female teachers partake in the underparticipation of their female pupils. A 1984 United Kingdom report issued by the Microelectronics Education Programme says much the same thing.

Once again, the debate sends us back to the starting point, to when and where stereotyped attitudes form in the young with respect to education and work and by extension to the strategic importance of primary education in the technology area. In 1985 the United Kingdom House of Lords Select Committee on Education and Training for the New

Technologies shows no doubt about this when it asserts that "the time when educational reform is most urgently needed is in primary school and in the early years of secondary school".

Lariccia and Megarry have commented on the implications of this gender discrimination for the position of women in the labour market. Women's traditional skills of patience, dexterity and accuracy mean that they dominate low-paid NIT jobs like data preparation, word processing and telephone switchboard operation, but they have made surprisingly small inroads into computer programming, systems analysis and software design. Whenever female aptitude for such jobs is tested, it is found to be at least equal to that of males. So the explanation of imbalance is not unequal ability.

During the years of impressionable adolescence, girls struggling to achieve a sense of feminine identity have to make choices (often perceived as irrevocable) about subjects to study and courses to pursue. Computers have an image influenced by their history of "male" concerns: wartime code-breaking, the space race, big business and high-technology industry. This is reinforced in young minds by the tendency of men to be the ones who own, use and teach others how to use computers. None of this is inevitable: Jacquetta Megarry describes how the INTER-ACTION Community Camps managed to reverse the usual sex ratio by deliberate marketing decisions. But this does require a conscious effort: thoughtlessness rather than outright prejudice probably contributes the more to sex-stereotyping.

Most developed countries are very short of talented NIT workers. Given the enormous industrial and strategic importance of this field, it seems wasteful to discourage (however unintentionally) the participation of half the nation in this way. The spread of microcomputers into primary schools (where they are operated mainly by female teachers) should help to dissolve the current association in young minds. Widespread adoption of creative and open-ended software in the arts and humanities would also help to dissociate computers from the mathematics and science departments of secondary schools. Making computers and NIT an integral mainstream part of the compulsory curriculum would help to prevent girls from opting out, but where the computer club is optional, self-selection will militate against equal female participation.

Special thought must be given to the problems that once-qualified women encounter when trying to re-enter the job market after a gap of some years. No field could be more forbidding to the re-entrant than NIT: an absence of even three years may be equivalent to several decades in other occupations. A general expansion of retraining opportunities would help. In the longer term, the development of more flexible ways of combining infant and child care with part-time employment of "permanent" status could remove the necessity for women to lose contact with the NIT field.

Chapter VI

TOWARDS POSSIBLE FUTURES

This report ends as it started, with an image of education as complex, dynamic, varied and tentative as it was before the coming of the new information technology. It has not altered the main features of the system – on the contrary it has emphasized them. The provisions newly designed as a response to its challenge are increasing the complexity and diversity of the curriculum, adding demands on the teachers, making their working agendas heavier still. The mythical status conferred on the technology by public opinion has combined with its objective merit in some sectors to generate yet another pressure on the educational institution towards yet another instrumental change.

The inequality of educational careers within the system has not been solved by the introduction of the technology, and its impact on the market of education has not failed to reinforce some of its pre-existing trends of development: that of formal innovation and experimentation, and that of non-institutional and/or non-formal educational provisions, both public and private.

However, to take the current situation as we report it as indicative of the range of impact of the technology on education could be rather misleading. Our analysis has perforce been made against data notoriously scarce and non-representative, from which definite conclusions as to the merit of the technology for education cannot be drawn with much confidence. Such conclusion has to await the diffusion of the technology of a high enough quality to the large majority of schools, when powerful hardware and software of quality will be available widely in education. Only then will we be able to verify beyond doubt the merit of the technology for delivering education and for facilitating learning of all children. Only then will we be sure that the beneficial impact of the technology can spread from the restricted situations of research and innovation where it is already visible to the ordinary classroom in schools and universities.

Nevertheless, it cannot be denied that the trends which have emerged from the analysis point towards an image of mass education that can be profoundly changed by the technology. If the data are not reliable enough to validate the hypothesis, they are convincing enough not to dismiss it. This is undoubtedly the reason why so many participants to the Conference focused on discussing what was happening and where it was happening, and gave little consideration to the comparative scale of the phenomenon. For them, the important indicator was the speed of penetration of the technology in education, already high and accelerating, which had brought so much hardware and software into so many classrooms, had touched so many teachers and so many children. That this portion was small compared to total numbers was not taken up as a matter of great concern. "Numbers will only grow", was the assumption implicit in their neglect of quantity and central to their concern with quality.

ISSUES AND DILEMMAS

The introduction of the new information technologies in education is under way in most of the OECD countries. The speed of development varies across the national borders, the policy approaches and the implementation strategies are also different from one country to the other, but the process has started and shows little signs of slowing down or to reverse motion. This is undoubtedly a first main conclusion to draw from the information analysed.

The same analysis shows, however, that far from witnessing a finished product, the situation we currently observe in many countries is still only an embryo of what the "new" educational world could be. Nevertheless, there is no doubt that the efforts have been important in a number of countries, that the financing has been sizeable, the motivation of all those concerned important (and the coverage by the media even more so), yet the aggregated results achieved so far in any education system as a whole seem to remain positively limited. But the situation keeps developing at a very fast pace, not least because of the technologies themselves, which persevere in progressing and transforming. This results in a high degree of uncertainty likely to surround educational courses of action for many years still. Any set of considerations on the future which we might develop here cannot therefore be but tentative and cautious.

Some of the issues and problems we have identified as central to the present situation will continue being so in the future, others will subside. Some of the developments will have to be planned for and worked out intentionally, others will take place regardless of explicit designs or investments. A correct diagnosis of what is likely to be short-lived and what permanent, of what is self-sustaining and what needs outside support, would undoubtedly be instrumental to effective policy and decision-making in this area of education.

The information gathered in Member countries as well as the Conference debates indicate the likelihood that issues and problems linked to quantities will, in due time, work themselves out. If the present level of investments in equipment, software and teacher training persists for long enough, the pecking orders currently established by policies – by educational level or line – will probably dissolve in not too distant a future. Given time, both vocational and general education establishments, post-secondary as well as secondary and primary, will have enough resources to use the technology in a tangible way. But tangible will not necessarily mean meaningful for education.

The transformation of present into future will be influenced for a long time to come by the evolution of two key factors at the heart of the current response of education to the technology. One of them we have called the "web of influences". The second has emerged gradually during our analysis and may reasonably be termed the "location of expertise". These two factors, enlarged upon hereafter, while not necessarily creating permanent problems or obstacles for education, do however generate a number of key dilemmas, for educational policy, for the institution of education and for research, which are unlikely to subside or weaken for a long time.

The Web of Influences

One way to look at the present situation is to see education as engaged in a vast exercise of trial and error. To the extent that the ultimate objectives are reasonably clear and the processes under control, we might be witnessing a first exploratory phase of development, marked by a healthy degree of uncertainty, progressing towards a clear future. In this case, the work agenda of all those concerned would not differ much from that of other times on other changes. It would then be reasonable to expect that the issues be defined within education and the problems solved by members of the educational community. The reading could however be different. The variations and uncertainties observed in the response of education to the information technologies could stem from elsewhere, from sectors of development obviously related to education but eluding its authority.

The existence of such "remote control" on educational developments (which we have already discussed extensively) is an important issue to debate. In responding to the technology, education cumulates its own demands and constraints to those originated elsewhere. The growth of information, the cultural and existential concerns, the impact of the technology on what is learned, how and to what purpose will remain central to educational agendas and will go on absorbing an important share of its resources. The evolution of markets – of technological products and of manpower – will keep forcing education to adapt to needs which might not necessarily accord with the broader mandate or priorities of education. The "bargaining power" of education with respect to these actors and factors has not been strong so far, because of its inertia at developing an influence of its own and because of its position (generally weak) as a producer and as a buyer in the technological market.

It remains to be seen whether education will be more able to counter, resist or escape the pressure from the "web of influences" than at present. The task will be all the more difficult if Lariccia and Megarry turn out to be right when they say that the future is already here: "The task is urgent. Society has yet to catch up with the implications of the first generation of computers. Already cheap artificial intelligence in the shape of fifth-generation computing is imminent, electronic networks are proliferating, massive data bases are being combined clandestinely and citizens' rights are continually being eroded. Governments and big businesses are not immune: the computer frauds and security breaches which are reported are clearly only the tip of a large iceberg, and the ease with which schoolchildren have been known to break into United States defence computers illustrates a potential threat to national security. Meanwhile, the number of components packed on to each tiny chip of silicon continues to double each year, dramatic reductions in the size and price of computer memory continue, digital electronics, videodisc technology and telecommunications innovations continue to converge, and recent advances in biotechnology promise to pose a fresh set of social and ethical problems. It is already later than we think."

The Location of Expertise

Few would dispute that in considering the introduction of the new information technologies, the core problem is to bring within education (its decision-makers, administrators and practitioners) a body of knowledge and expertise that does not belong to it, but mostly originates and develops elsewhere. Micro and minicomputers are part of the latest developments in electronics, their programming is primarily performed within the world of informatics, their most advanced applications are to be found in research laboratories and in the economy, in both the production and the service sector. To translate all this into educational applications is neither easy nor straightforward. Such an objective can only be achieved if a number of conditions, all difficult to obtain, are reunited. The system of education is not strong at communication and exchange; yet this is the task to embark on if a large enough body of experience of the technology is to be grown inside the system to ensure soundness as well as autonomy for the decisions taken there. The cost-effectiveness of achieving such "critical mass" depends heavily on a number of barriers of communication and exchange being lowered.

First candidates are the barriers between education and research, private and public, and between educators and other professionals, such as in the electronics industry and software development sector, as well as psychologists and artificial intelligence specialists. Many gates between these different locations of expertise need to be opened from both sides by a shared willingness to co-operate if the objective of quality – the only thing worth aiming at for all our children – has any chance of being attained. Examples of success are not lacking in several countries but they have so far remained marginal to mass education as well as disconnected from one another. The problem of how to achieve the objective on a larger scale remains so far unsolved.

Some of the bottlenecks are more evident than others – for instance the difficulty of establishing partnerships and co-operation between educational and non-educational agencies, between different sectors within education, and across different countries. In this context the role and function of teachers is one of the chief issues to be clarified.

As Rhys Gwyn has pointed out, there are a number of recognisable circumstances that inhibit an adequate participation by teacher educators in research in this, or in many cases any, area. In some education systems, research as such is not seen as the province of teacher training (which in many countries is less than fully accepted by the tertiary level "academic" community); elsewhere the heavy demand for training in respect of information technologies and education leaves those able to offer the training required with very little time indeed for research. This problem in fact extends beyond research; it is common to hear colleagues who train in the uses of the new technologies complain that their commitment to the professional development of others leaves little or no time for their own.

Clearly, the further strengthening of resources in these ways would do a great deal to enable teacher education to meet the NIT challenges. What are additionally needed are the two elements already identified: a more effective link with research and development, and, in some countries, clearer policy lines for development. Each of these, of course, feeds from the other, and it is worth examining more closely the ways in which research and development could aid the better formulation of policy guidelines.

Scientific research has an extremely important contribution to make. It is essential that developments in the field of teacher education should take cognisance of advances such as those in Artificial Intelligence and storage technologies. Additionally however, the construction of a strategy for the training of teachers has to take into account other developments, covering a wider range: these include, for example, the use of public data banks as resources for learning, enhanced uses of the broadcasting media for the delivery of learning packages, examination of new patterns of work and leisure, and questions of individual privacy. Responses to such a wide range of phenomena, which embrace technological development, pedagogical application and social implication, are surely too complex to be decided by any one sector alone. What happens in education as a consequence of these new developments – in short, what teachers in the future will do, what functions they will fulfill – cannot be determined solely on the grounds of technological/scientific trends or by *fiat* of political leaders – and certainly not solely by teacher trainers having to make up their own minds about what to teach.

The lack of communication and exchange across educational levels and disciplines has also emerged clearly as a serious bottleneck. Some would query the urgency with which a solution is claimed to a problem which is as old as education itself. Yet, the stakes implicit in the challenge of the technology – extending well beyond a mere redefinition of curriculum and discipline boundaries – makes the issues particularly worthy of attention. One of the most immediate tasks is to clarify the role and function of higher education – the depositary of most of the capital of technological expertise held by education – with respect to its own response to the technology as well as the response of less senior educational levels. Should there be an explicit definition of responsibilities at the policy level? How to harmonize it with the traditional autonomy and specialisation of universities? How to reconcile this with established corporative needs and demands? With administrative constraints and reduced budgets? With its own "crisis", and the identity search of this sector of education? Debates on issues such as these will no doubt mobilise much of educational resources in the years to come.

A last point we should take up in this context is the different speeds of technological development across OECD countries, where the variations emerging in industry and the economy are already being reflected in education and threaten to produce even wider variations in the future. Many today voice the same concern expressed by Ms. Helena Carvalho Santos, Secretary of State for Education from Portugal, at the opening session of the Conference: through technological dependence on education it is the whole culture of a country that is put at risk. Although few would disagree with such a contention, the issue of the location of expertise elsewhere than in one's country has found little place so far in either policy or political agendas.

Yet, as Rhys Gwyn has pointed out, the problems involved might not be as insurmountable or as country-specific as they look. "Given the broad similarities of socio-economic organisation which override the cultural differences between most of the developed nations, it is reasonable to see the educational problems posed by the new technologies as being, again broadly, the same from country to country; the technology itself transcends national boundaries. Yet anyone involved in examining the NIT/education phenomenon at the level of Europe only, let alone the wider membership of OECD, has to be conscious of how little is done, in real terms, to share development costs in what is, by normal education budget standards, an enormously costly phenomenon. It is not difficult to envisage the benefits that could flow, in terms of experience gained, insights shared and, also, concrete joint actions on, for example, software, if it were possible to establish a network of the kind of developmental settings across countries. It would not be necessary for each to follow a shared line of development – indeed, the reverse. Since the future pattern of educational use and provision in the wake of the NIT cannot be predicted, it would be immensely valuable to have a number of linked but separate and diverse activities proceeding in parallel but sharing from each other's learnings. Strategies of this kind, admittedly, go beyond what has hitherto been attempted: we are talking of curriculum development on a very large scale indeed. But the point is precisely that it is development on this large scale that the new technologies may demand."

These considerations capture the essence of much of the current response of education to the challenge of information technology. They also set the ground for the attempt we shall now make to clarify some of the dilemmas presently confronting education.

Dilemmas for Policy

The achievement of "critical mass" while coping with the web of influences and the location of expertise outside education, has generated a number of dilemmas for policy. One is that of trading efficiency for equity. Another is that of taking educational risks (possibly) above the means of education. By now, everyone has become aware that the introduction of information technology in education is a very costly exercise. In times of tight educational budgets, it is therefore no surprise to find that the resources available are not enough to meet all the needs simultaneously. In particular the means are inadequate to promote development equally across each of the fronts identified as critical: equipment, curriculum (and software) and teacher training and even less sufficient to achieve meaningful progress in each school and university. The alternatives offered to policy have ranged anywhere from a maximum of efficiency – total concentration of resources on some educational establishments and on some of the fronts – to a maximum of equity – total spread, however thin, of resources across all the targets. Obviously, any approach in between produces speeds of development towards achieving "critical mass" that can correlate only negatively with degrees of political popularity. Faced with the riddle, most national policies have opted for a compromise: most of them have established priorities for investments, by front and/or by level of education, no one being fully served nor totally neglected. Given enough time and an undiminished supply of resources, such a staggered approach will provide, almost by definition, the optimal solution, where efficiency and equity are both achieved at best. Meanwhile, the choice is not immune to risks.

Another way of picturing such a common policy approach is to see it as building towards the top by piling up "incompletes": schools are given a little additional equipment at the time, software libraries are expanded much at the same (low) speed as the cohort of trained teachers, while progress towards growing expertise within education is obviously slowed down. Strategies such as these have indisputable political merits: perceived discrimination is least, the number of schools with some equipment does not cease to increase, software libraries grow in each school as do the numbers of teachers being trained. They are however plagued by an unavoidable risk, proper to the approach: these strategies make success heavily dependent on continuous support for the longest time – a very scarce commodity in today's education systems. Tangible results depend critically on the achievement of high enough levels of development in all areas. If developments stop anywhere on the way, results (thus sound justification of the investment) may well turn out to be considerably below anyone's perception. The concern with equity, then, runs the risk of producing wastage and generating frustration in the system as well as outside it. In this case, the price for short-term popularity can be large indeed in the long run, larger perhaps than education can afford.

Dilemmas for the Institution

The merits of information technology for large-scale teaching and learning are only just being explored – this is a shared opinion. Equally shared, on the other hand, is awareness of the powerful impact the technology can have on systems and organisations when it is introduced efficiently, effectively and above threshold levels. In the sectors of society when this has already happened (as in production and service) the effects are clearly visible. Systems have been changed profoundly, their structure and organisation as deeply affected as the conditions of work they offer. Some have been altered beyond recognition.

Such power creates a dilemma for the institution of education. This is a system of service delivery organised on a specific formula – phrased in terms of location and organisation in time and space, teaching/learning methodologies, ratios of adults to children, manpower profiles and the like – which has survived practically unchanged for much longer than many other service delivery systems. There is every reason to believe that information technology, if and when introduced efficiently and effectively in education, would alter it in ways comparable to what has happened elsewhere, and would make possible alternative institutional models equally or even more cost-effective to deliver the same service. This produces a chief dilemma for the institution, linked to its very survival in its current form. To push the argument to the extreme, the institution of education, by being too efficient at exploiting the potential of the technology to improve its own structure and organisation, risks working itself out of the job.

The general economic climate (one of the influences in the "web") forces education to engage in this internal transformation. The establishment of partnerships and co-ordination with other parts of its own system as well as with other systems – unavoidable given the dispersed location of expertise – is also pressing education towards meeting this particular challenge of the technology. Field developments show how the process is already in motion. The analysis of strategies of implementation has shown the complexity of the operation in terms of the bodies involved, at the centre as well as at the periphery. It has also shown the existence of sometimes strong local expertise, motivation and sources of financing and control, with which more formal initiatives have to contend. In this context, whatever the policy strategy adopted to achieve critical mass, the success of its implementation depends rather crucially on the establishment of an adequate degree of co-ordination between the various partners involved. Concretely, this means the creation of institutional bodies or the setting up of institutional arrangements which are not necessarily in tune with the traditions of the system.

Few of the countries are so far ahead in the introduction of the NIT in education to have had to find an overall solution to the dilemma, although instances exist by sector. France and the United Kingdom are telling examples. Basically, the two education systems could not be more different: the one highly centralised, the other its opposite. Yet, when designing the institutional arrangements designed by each to deal with the introduction of information technology in education, they are much closer than their parent systems are apart. The solution has been to establish a unitary structure, depending from the central education authority which overlooks and co-ordinates the whole process while leaving enough room for local initiatives. The "Agence pour le Développement de l'Informatique" and the "Council for Education Technology" perform basically the same task with respect to the education system and have essentially the same prerogatives with respect to more decentralised agencies. Here we can discern an institutional strategy dictated more by the nature of the implant than the receiving tissue.

The establishment of a unitary structure to co-ordinate and control developments, thus to facilitate and accelerate the achievement of critical mass, can be found in a number of other OECD countries. More often than not this structure takes the form of a special body defined within or dependent from the education authorities. This is the case of, for instance, Sweden, Belgium and some of the provinces in Canada. Next to this, some forms of larger co-operation have been introduced such as the consortium linking the three Australian states of Tasmania, Western Australia and South Australia. In general, as in the United Kingdom and France, these institutional structures depend from the education authorities. Unlike these two examples, however, their field of relevance is usually more limited. The front more often addressed by these structures is, once again, equipment, followed closely by curriculum development, sometimes by software and, only erratically by teacher training. In all cases the success of the enterprise remains critically linked to the readiness of the parties concerned to transcend established institutional rigidities and prerogatives and exchange and cooperate across administrative borders.

Dilemmas for Research

A third dilemma faced in the achievement of critical mass within the conditions set for education is for research. All through this section we have spoken of "critical mass", yet we know very little as to what the concept really amounts to, either globally or specifically. What does "critical mass" mean in terms of equipment for a country, a region or a school? What is the "critical" computer-related curriculum time, below which no effect can be expected on the learner? How does the concept translate in terms of size of the library of software? How many hours of courseware do we need to produce to achieve the desired educational objectives, by level of schooling or by discipline? How many teachers do we need to train, and for what?

Of course, if one had the time and the resources to conduct all the research and experimentation needed to answer these questions, there would be no dilemma. One would just wait to gather enough information and be in a position to define the targets properly. Only then would one turn the matter over to the policy-makers and the administrators to design the optimal strategies. But that is not real life. In real life the time constraints are usually as ponderous as the resources are light. Yet decisions have to be taken without delays, on whatever information is available, however limited it might be.

Few of the OECD countries have taken the decision to delay the large-scale introduction of the NIT in education until research and experimentation are completed, at least sectorially. The few examples that exist concern chiefly the curriculum. Among these one could mention Sweden, where a systematic plan of research has been carried out since the turn of the 1980s to decide on possible subject-related computer utilisation (the projects DIS and PRODIS) and on the possibilities of Computer-Assisted Learning. Another example comes from Switzerland, where experimentation is also going on in terms of curriculum innovations in the last year of upper secondary education. Research programmes also exist in a few more countries to assess the forms under which the computer can enter the primary schools.

All these examples come from the world of schools, and are all submitted to the scrutiny of the education authorities. It is doubtful that these kind of initiatives would, alone, allow the solution of the dilemma in any short-term perspective. To go faster one would need to tap at expertise built over the years on the same subjects but in different territories such as the research community and the private sector. Pierre Duguet has offered some insight into developments in one of these sectors – research institutions – through an analysis of seven country surveys communicated to the CERI Project. The areas of research specified in the surveys' questionnaire included "hardware for educational purposes", "systems for educational applications", "educational application software", "the learning process", "social and psychological issues" and "programmes directed at professional development and training".

The information from the 122 research institutes covered by the survey (101 of which were universities or higher education establishments) has been classified by Duguet in terms of declared research priorities. The most popular research area (between 65 and 75 per cent of activities) is the identification of input and output devices, CAI authoring languages, Computer-Managed Instruction, computers applications for the laboratory and for data-processing, and man-machine interaction. Only 30-39 per cent of the activities reported were in the areas of individualised education, teacher training, hardware development, the use of data banks, viewdata, etc., the use of computers for remedial education and the handicapped, and the diagnosis of learning difficulties. Even fewer (around 20 per cent) were the activities devoted to learning processes, to social and psychological aspects of introducing the new technologies, to professional training programmes. Fields in which research activities have been found to be low (less than 20 per cent) are "distance learning", "software and courseware portability, including telesoftware", "social questions such as equality of opportunity for access to the new technologies in terms both of understanding and educational use, according to social and cultural background and sex" and "ergonomic and medical aspects".

Also interesting is the information provided on the levels of financial and human resources attached to these activities, which – as Duguet says – can be ranged in four categories. First are the smaller groups, most with no outside funding of between 0.5 and 3 man-years. The majority of these are teachers researching in mathematics, physics and education sciences who have decided to focus their research on educational applications of the new technologies within their own teaching departments. Then come the medium-sized groups, many with more or less modest outside funding, of between 4 and 8 man-years. The larger groups follow, with substantial resources, of 9 to 15 man-years. Finally, there are the research centres and institutions with substantial financial and human resources, of 16 to 100 man-years. Examples are Harvard University's new Education Technology Center in the United States, the University of Calgary and the University of Waterloo in Canada, London

University and the Open University in the United Kingdom, and the Institut National de Recherche Pédagogique, and the University of Paris VII in France.

This information – warns Duguet – must be treated cautiously, as not all institutions quoting resources in man/year terms specify whether their figure means the number of researchers per year or the number of researchers multiplied by the number of years the contract or programme runs. Harvard University, for example, quotes 108 man-years for research over five years, i.e. about 22 researchers. Nevertheless, the human resources level would appear to be of approximately the same order in Canada, the United States, France and the United Kingdom, with the majority of research groups comprising between 4 and 8 man-years and just a few very large groups. Australia seems mainly to have the smaller groups of 0.5 to 3 man-years.

The conclusions of the survey are short and precise: the resources being allocated for R&D in educational applications of the new information technologies seem low in view of the challenge they represent for education. More time, resources and co-ordinated efforts, nationally as well as internationally, are therefore needed to reach a research capacity commensurate to the present need to know.

OBJECTIVES

At the closing session of the Conference, John Steinle commented on the state of the art in this area and the broad options available to chart the future: "We shall leave the Conference in the knowledge that we are in a position akin to that of Gutenberg. We have devices at our command which we are keen to see used and which we are confident will prove useful. We are not at all sure, however, where they will take those at whose disposal they are to be placed. Even those countries which have gone the furthest in their adoption of the new technologies and who have developed and begun to implement comprehensive plans, have chartered their courses largely as acts of faith. In terms of strategies, there appears to be a surprising degree of consistency among Member countries. There seems to be general agreement that the new information technologies present educators with fairly clear options."

The first option, according to Steinle, is to reject the NIT or to make superficial and ineffective use of them as we have done with earlier educational technologies. This, of course, does not mean that we can ignore them as they are changing our societies profoundly, and as the reflector and transmitter of the cultures of our societies, educators must recognise them and decide only upon their use. The second option is to accept the NIT uncritically as aids at a time when education is under a cloud. Such a course is enticing as it promises renewal of the curriculum, the removal of the drudgery from much of school teaching and learning, and offers us the prospect of placing the world's storehouse of knowledge in every classroom. But these advantages are, as yet, promises. They are uncertain and untested.

The third option which presents itself is for us to accept the new technologies critically as offering us assistance in our efforts to achieve our educational goals. It is this position that seems to have been generally accepted by the Conference. Thus the real choices for education remain the same as ever. They are choices among values: what knowledge is worthwhile, what constitutes a good person and what constitutes a good society? These are the fundamental questions which every country must decide for itself with or without the new information technologies.

In facing these choices education can still welcome the enormous increases in potential for ways of reaching its goals for the new technologies offer new ways and means of delivering education at a time when they are sorely needed. They cannot, however, replace the human relationships which are at the heart of real education. Most countries seem to agree with this, and are now endeavouring to decide the speed at which they should proceed. In short, and contrary to popular belief, it is probable that the rate of developments in the use of the NIT will depend not only upon the availability of machines, but upon the availability of people and knowledge. "So, (Steinle concludes) in introducing technologies which are devoted to assisting in the ordering of knowledge and making it accessible to more and more people, it is a nice irony that among our first priorities should be the need to seek knowledge."

The pursuit of knowledge goes through the achievement of objectives of quantity as well as quality. We have already shown how the former of these objectives have been established as the object of policy, materialising as either explicit targets (such as for equipment and for numbers of teachers trained) or in terms of priorities of investments, such as those giving preference to the introduction of the technology in vocational rather than general education courses. Qualitative objectives are more elusive. In policy they appear more as conceptual recommendations than concrete targets for action. At present, quality – the pursuit of knowledge and understanding – is better aimed at in areas still uncovered by either formal directions or commitments countrywise, such as in the fields of research and development.

Research and Development Objectives in Selected Countries

Pierre Duguet has reported on recommendations put forward between 1981 and 1984 in the United States (Office of Technology Assessment, 1982 and United States Department of Education, 1983), the United Kingdom (Sage and Smith, 1983), France (Le Corre and Pair, 1981 and Carraz, 1983) and the Netherlands (Netherlands Ministers of Education, Science, Economic Affairs, and Agriculture and Fisheries, 1984). The guidelines put forward in these reports are sometimes cast against the specific national situations and preoccupations. One from the United States, for instance, phrases its recommendations in terms of the declined federal support to R&D: "in the late 1960s, the Federal Government funded a number of research and development projects in the use of Computer-Assisted Instruction. Over the last decade, Federal funding for R&D in educational information technology has dropped precipitously"... "Much remains to be learned about the educational and psychological effects of technological approaches to instruction. Not enough experience has been gained with the new information technology to determine how that technology can most benefit learners or to predict possible negative effects of its use. Given this insufficient experience, caution should be exercised in undertaking any major national effort, whether Federally inspired or not, to introduce these new technologies into education". The United States Congress is therefore advised by the Office of Technology Assessment to consider developing policies designed to ensure optimum use of technology and directly to support R&D in those areas; to encourage private sector investment both from the foundations and from industry; or encourage a combination of both by using Federal funding to leverage private investment (Office of Technology Assessment, 1982).

The other United States report stresses the need to involve manufacturers in the process: "Realising the full potential of the computer in education requires ground-breaking research that will allow educators and manufacturers to proceed confidently in the development of advanced computer-based materials for the schools. Earlier Federally-supported research provided the basis for the Computer-Aided Instruction of the last decade and a half. Another such research programme is now needed to take advantage of the vastly increased capability of affordable computers" (U.S. Department of Education, 1983).

Cultural and social concerns are voiced in the French reports alongside the industrial and the educational ones: "Research on teaching applications of computers should be developed and enhanced with a view to developing worthwhile facilities, with an eye to product quality and to remedial applications, preparing for the cultural and industrial effects and controlling adverse aspects, such as accentuated inequalitites, robotisation, threats to privacy" (Le Corre and Pair, 1981). "The aim of R&D being not to see how hardware can enter the education system at all costs, but to what extent it could improve learning and education; how it could be prevented from fostering new forms of inequality and what effects it would have on the functioning of the school" (Carraz, 1983).

Besides their national outlook, all reports also share a similar concern, expressed through the stress they put on the need to invest more in research and development, without forgetting policy evaluation. Their ongoing preoccupation is on ways to maximise the educational benefits of the new information technology while achieving the best possible degree of control over its applications.

As to the specific agendas proposed by each report, they are, to an extent, different. The United States Office of Technology Assessment concludes on the needs for R&D focusing on: developing new techniques and tools for software development; developing the human/machine interface; and improving the understanding of cognitive learning processes. The report from the United States Department of Education recommends a broader list of research areas, including prototype research which will provide the necessary knowledge and experience for subsequent development of instructional systems and materials by private industry and schools, and fundamental research in laboratory settings on processes involved in skilled reading, writing, mathematics, science, and other intellectual activities. Other topics recommended are new ways to adapt instruction to individual differences in aptitude and progress in learning, and the psychology of student and teacher interaction with automated instructional systems; associated fundamental research in specific activities from which shorter-term payoffs can be expected, e.g. the enhanced design principles for human/computer systems for education; research on cognitive issues, including resistance to the changes involved in this type of learning, improvement of understanding, reading and writing, knowledge structure, mental models and cognitive psychometrics; research into other areas including motivation, the introduction of computers into education, the computer as an aid to the teacher, teacher training, school and class organisation, quality and assessment.

The United Kingdom report identifies research priorities that are closer to the functioning of the education system, namely: learning processes, assuming highly interactive software, focused on the styles, strategies and process of learning with information technologies (this would involve investigating individualised learning, distance teaching, associated information handling skills, software conceptualisation principles, social interactions, expert systems for education); the impact of technologies on curriculum and the efficient management of changes in educational practice and organisation. The two French reports propose additional breakdowns of the research items. R. Carraz suggests work on: diversified ways of using the computer in teaching situations, starting with an inventory of existing practices; mechanisms for expressing and understanding audiovisual messages, taking account of learning styles and of how the neurosciences are beginning to describe those mechanisms physiologically; the use of the re-recordable videodisc; the use of computers as part of teaching practice; underlying operational concepts (memory, program, switching, coding, etc.) and on the various forms of awareness and construction by pupils: taught or self-developed; the introduction of these technologies and educational applications within a broader cultural framework (technical culture dimension); the arrangements for introducing technologies as training tools in industry; artificial intelligence, cognition and educational software design with a view to devising expert systems and languages with which the user can program more independently.

Le Corre and Pair recommend research on: terminal specification (especially videodiscs); features of communications media; nature and presentation of information for exchange; man/machine interaction for education, information and documentation; forms of distance teaching; educational software design; problem-solving; educational games; social and psychological aspects; involvement in local community; ergonomic aspects; assessment; special applications to various categories of the handicapped. Special education is also mentioned in the Dutch Informatics-Simulation plan recommending research on: applications of information technology to special education; the development of hardware, software and courseware in association with the industrial sector; as well as the setting up of experimental projects giving practical results for an immediate demonstration effect.

In these lists the similarities are recurrent enough across the seven countries for Duguet to identify research topics on which international co-operation is already possible : Computer-Assisted Instruction (CAI) in multimedia hardware configurations based on programming languages capable of developing student creativeness (e.g. Logo, Micro-Prolog), educational software production, authoring languages and expert systems, and the use of the computer for a better understanding of and improvements to learning processes, to be applied first as a remedy to school failure. Additionally, an area where it is becoming increasingly obvious that international co-operation would be particularly fruitful is the interface between microcomputers and simple and complex machinery. This would involve developing highly interactive software, whose *cores* could be transferred unmodified for different hardware configurations, thereby ensuring portability, from the teaching standpoint, from one country to another, with countries making themselves responsible for any additions necessary to reflect teaching, cultural, social, historical or geographical considerations of their own. It would be hard to overemphasize the importance of achieving pedagogical portability of software from advanced countries to the less advanced countries, since good software costs so much to devise. Needless to say, agreements should be concluded among the advanced countries about copyright, so as to make transfers to the less advanced countries acceptable.

Recommendations from the Conference Working Groups

By the end of their debates the working groups to the Conference had agreed on what the working agendas for the future should involve alongside those on R&D. The quality objectives they formulated touch upon research as well as policy and institutional matters.

Policies, strategies and tools of implementation: This Group formulated recommendations as to the possible role of an organisation such as the OECD in the area under review. It emphasized the general need to evaluate progress and exchange information across countries: those with the longer experience in educational applications of the technology should inform the others of "what works", of cost-effectiveness and benefits, and of any unanticipated adverse effects encountered. It also recommended the study of effective strategies for mediating school change, with particular reference to the shift of power among stakeholders in the school world. The training of senior educational decision-makers was deemed essential for sound decision-making in this area, at least as important as disseminating information on existing educational software. On the curriculum front, this group focused on computer literacy. Having acknowledged the large variations in length and content existing across courses and their likely speed of change (high, as people at large become more familiar with technology and as computers become more user friendly), it recommended that the changes be monitored and the educational decision makers informed. A similar effort at establishing international co-operation and disseminating information should concern the world of research. Finally, the group concluded that we have to reconsider our cultural values and, in the light of this, the objectives of our education system. The deep relationship between NIT and education calls therefore for a review of the cultural patterns and the educational models that underlie the syllabuses of different disciplines. To face the challenge of an "information society", the relationship between knowledge learned and know-how to be learned needs to be reconsidered. This is not a concern for any single country but a mondial one, which can benefit greatly from international co-operation.

The impact on learning: This Working Group agreed that the learning of computer programming should be in the secondary cycle and in pre-vocational streams and that there are still doubts about the pedagogical value of earlier initiation in computer logic as an alternative mode of logical reasoning. The cognitive sciences were therefore challenged as to whether and how such "reasoning" could be applied in other areas. The Group also agreed that, as a tool for the purposes either of teaching or of data-processing, the computer in its instrumental aspect is perceived differently, depending on whether the focus is on its effectiveness, the irreversibility of its use in the productive system or the risks of widening social inequalities and the illusions it may nurture. For these reasons the future working agenda proposed by the Group involved research on information science as the instrument of an epistemology of knowledge (including the acquisition of mathematical reasoning and scientific concepts), cognitive processes, transfers and learning processes, as well as the representation of concepts and communication of knowledge.

In the general area of computer science and organisation of learning processes, the objectives recommended included research on stratification by learning age (primary, secondary, mainstream/vocational education); the organisation and management of time and place of school learning (frequency/timetable, computer access and utilisation rate); and, the paradigm, individualisation of the learning processes and the socialising function of school. The Group emphasized also the need for pedagogical evaluation of the knowledge acquired by learners, of differences between individuals and groups, of the efficiency of the methods chosen by teachers, and of scholastic results and performance.

As to the specific use of the NITs as a data-processing tool, the recommendations covered research on the use of word processors, the consultation of data banks: learning how to search for, process and store information and applications in the productive system (electronic currency, robotics, office automation, etc.).

Changes in curricula: In addition to stressing the need for co-operation and exchange across countries in the areas of software and hardware development, this Working Group emphasized the growing importance of partnership of schools with industry, social organisation, trade unions and universities, pending the solution to the central issue of control over the curricula and the quality of the educational process. Specific recommendations were issued in terms of the introduction of information technology in primary education, the reconciliation of the differences between the traditional curricula and the NIT-based curricula, the integration of NIT in different subjects, the definitions of quality standards for educational software, the development of approaches to teachers' training, the introduction in the curriculum of considerations on the societal implications of the technology.

New teaching functions and related training: Here the recommendations covered studies on the changing role of teachers in the context of cultural/structural expectations, in association with the relevant teaching interests, on the emerging roles and functions of the NIT co-ordinator, on strategies relating both to teacher training and to the training of teacher educators. The Group also recommended the establishment of a data base of basic data about pre-service and in-service teacher training programmes, across countries.

Software and courseware for a multimedia educational environment: The Group here expanded the general consensus on the need for a much-increased and better-structured flow of information across countries by recommending the creation of an international network to this effect, reuniting schools to colleges and universities. The Group saw the network as a series of nominated national centres linked to an international one, providing effective channels of communication to schools, colleges and teacher training centres. Within this context of enhanced communication, the groups gave the highest priority to "portability", i.e. to the establishment of standards for software and hardware production as well as for cataloguing, describing and evaluating software and courseware for authoring systems, software tools and graphics. The final recommendation from the Group was for increased support for both pure and applied research on the role of computers in education in Member countries.

Out of such large priority lists, the areas of enquiry for the second phase of the CERI project on "education and information technology" have thus been selected. This project, running until the end of 1986, will be concerned solely with the educational uses of the new information technology – present and potential – thus disregarding the more strictly vocational objectives. The selected areas are the evolution of policies and strategies for implementing NITs to improve teaching and learning and evaluation of the results of such policies; the assessment of selected pilot experiments involving the large-scale use of NITs to enhance teaching and learning and to facilitate access to education; the contribution of NITs to improve the learning of basic skills – in compulsory and adult education – and to a better understanding of the related cognitive processes.

Selection Criteria for National Research Projects

These recommendations by groups of specialists and practitioners for working agendas should prove of considerable interest to countries planning or structuring their research programmes. Indeed we would hazard that the future of learning and the NIT will be largely determined by the wisdom shown in choosing one agenda as against another: these add materially to the options available. Thus specific areas where future efforts will be concentrated will be selected by criteria which will inevitably reflect the different interests and priorities currently at play. Some of the decision-making could focus on pure research needs, others on more immediate pay-offs for education, or on economic or market imperatives. Yet other criteria would be chronological considerations, on how to achieve visible progress in the shortest possible time, while reserving a medium- or long-term perspective to commitments and investment that are not economically or politically justifiable in the short run.

A "cognition agenda" could, for instance, be established in the area of "learning processes" which would focus on specific aspects of learning as it takes place in education. In this agenda one would find issues related to the time organisation of learning, such as its acceleration, or its sequential organisation, as well as issues more directly relevant to developmental models of cognition. Possible lists would also comprise research on specific learning processes such as strategies of thinking, including errors, problem-solving and concept formation, as well as topics on information-processing such as orientation, anticipation, cue-selection, perception, recognition, short- and long-term memory processes. An important place in this list would be devoted to the study of the cognitive benefits of learning computer programming and especially of its transfer value.

Concerns that could be called "existential" could also be part of the "cognition" agenda, recommending research on the effects on learning of looking at "reality" through the technological glasses, on the consequences for learning of the specific motivational and attitudinal factors triggered by the presence of the NIT in the learning environment, on their impact on interpersonal behaviour as well as on personality development. An important place in this list could be devoted to the impact of the NIT on the balance between "algorithmical" thinking as opposed to creative or lateral thinking.

A pedagogue concerned with the impact of the information technology on learning – to remain with the same example – could draw a list from a different perspective. His general guideline would be the assumption (examined in Chapter III) that the most promising role of the NIT in pedagogy is as *translators* of established cognitive and pedagogical thinking in models to be used currently in pedagogical practice at affordable cost, and as *evaluators* of the effects on learning.

At the core of possible lists under this heading one would find the development of "real time" monitoring and evaluation techniques, of models of independent learning, of automatic assessment of errors, of rapid diagnosis of the profile of learning aptitudes. In other words, in this list the pedagogue's list would include the development of NIT-based connotation applications of innovative pedagogical methods. Given its cost-efficiency connotation, additional items of this list would also include specific considerations of the hardware requirements for desirable pedagogical objectives and their cost implications.

An educator would adopt yet a different approach to the same problems. His, or her, working agenda would include specific items related to the large-scale introduction of NIT-based learning methodologies in the familiar school settings. An important item on this list would concern the effect on learning of transferring experimental learning methodologies to ordinary school situations. The list would also include items concerning the impact on NIT-based learning of organisational variables such as the organisation of the learning environment in schools in terms of time, space and human interaction with other learners as well as with the teacher. An additional item would concern the analysis of the impact on learning of teaching practices that use the computer as a support alongside other supports without giving it the most prominent position.

This working agenda would rather be concerned with the reality of schools, the ordinary school population as well as the established school curricula. On the former front, the list would include items on the personal profiles of the learners, in view of identifying the traits of those who learn best and those who learn least with the NIT and the reasons why. On the latter front, the items would include the development of curriculum prototypes, whereby the benefits of learning with the NIT could be ensured and/or safeguarded in new curricular organisations of known or new disciplines. In particular, this list would give much space to the applications of the NIT to the acquisition of basic skills, such as reading, writing and numeracy as well as the development of new curricula centred on NIT-related knowledge and skills, aimed at achieving specific cognitive gains.

The examples above are only indicative of the complexity of the task at hand. A single problem area (in this case learning processes) can originate different working agendas depending on the constituency. The resources available would hardly allow that all be investigated, yet each part is an equally important piece of the puzzle. How to establish priorities and co-ordination among investments will be a central problem to solve in the years ahead. Once again, the crux of the matter will be time.

To take an example: there is an obvious and urgent need to invest in the area of education and the NIT. The new information technologies, essentially microcomputers and particularly the least powerful among them, are entering the education system in ever-increasing numbers, and they are entering homes in numbers even larger. In the absence of action to the contrary, it is likely that bad habits will develop and consolidate in the school population, that the NIT will generate new forms of social discrimination that will reinforce the old ones, that expenditures in education or training would remain at unaffordable levels for the general economy.

While the new information technologies are growing, we are passing through that especially privileged early phase when most of the ground for future developments is being laid down, often irreversibly. It is extremely important, therefore, that now, rather than later, we establish as clear as possible a diagnosis of needs and priorities, and act accordingly. When considering the introduction of the new technologies in the formal education system, and relevant research and development investments, it is clear that in the decisions taken there will be little room for trial-and-error strategies.

To have noticeable effects, the investments in resources, at all levels, are bound to be large. Past history has shown that when large sums are involved in setting up a new system, subsequent corrections are almost impossible to introduce. Large investments produce visible effects, but they also produce rigidity in the system and inertia towards modifications. The larger the financial investments in a system, the more costly the eventual adaptation to changes. The larger the number of people involved in the production process, the larger the production but also the more difficult the eventual modification of the production itself, should the need arise. Given the degree of ignorance we still have as to the likely deep effects of the new technologies on education, it would certainly be hazardous to invest massively at the beginning on the basis of choices that might well turn out to be premature.

Yet, if we do not invest on a large scale at the present time, we will not have the information we need to take further decisions, we will not know how best to ensure equality of opportunities, how to modify curricula for different ages of the school population or different courses of studies. The dilemma of initiating actions that are bound to generate gains and losses simultaneously is a very familiar one to policy-makers. No doubt, the same care will have to be used in the field of NIT and education as has been the case for other educational transformations. In this respect, at least, the new information technologies have nothing new to propose.

RESPONSIBILITIES

More than enough has been said already to establish that the potential of information technology for education is unprecedented in content as well as scale; and that in responding to its challenge, education has to face a number of problems and dilemmas that originate within the system as well as outside it. The economy, society and the national culture all generate problems for education, which are then dubbed – often erroneously – as educational. It is no new thing, therefore, to have to sort out what are education's specific responsibilities in situations where responsibilities are, or should be, borne collectively. The identification and allocation of these joint responsibilities is, of course, central to the response of education to the new information technology. Yet, this issue tends to be overlooked in policy formulations and neglected in the debates. Although only a detail of the total agenda, the approach to computer literacy is one of the most telling examples of such irresolution.

Computer literacy is an area where most of the educational responses have come from the non-institutional and non-formal sectors, with varying success. It is also where many observers look for clues as to desirable changes in the system of mass education. More than this, to some minds it qualifies as the strongest competitor to formal education, in the matter of service delivery to everybody's satisfaction. Not many recognise, however, that the growth of this peculiar "computer literacy" sector is scarcely relevant to the institution of mass education and that it is not the prime responsibility of education to accept its challenge.

Mass education is responsible for defining and transmitting a body of knowledge and skills deemed necessary to society as a whole. In the proteus-like network of "computer literacy" courses, curricular content is far from being clearly defined or shared across programmes. Yet, education is often encouraged to take them as an example and assume itself the responsibility of providing the same to its constituency. The panel discussion at the Conference was as heated on the subject as other similar debates in other forums. There were those in favour and those against considering computer literacy a "must" in today's society alongside other traditional literacies. Each party would bring learned arguments to support its position, Joseph Weizenbaum insisting on the human limitations of technological applications and on the human ability to learn what is needed to use technology without technical knowledge, and Jacquetta Megarry and Giovanni Lariccia insisting equally firmly on the need to know how the technology works. The discussions were passionate and extensive, yet most of them failed to acknowledge the key issue of the responsibility of the system of education in this area. This was pointed out cogently by George Papadopoulos, who emphasized that, although there is no disagreement as to the massive penetration of the information technologies in society and their impact on its functioning, this does not necessarily mean that the education system itself, or indeed education *tout court*, should necessarily become obsessed with the need to develop artificial responses to the situation. More so, one would add, when the spin-off of intense technology development does not seem to be that educationally brilliant for the community, as shown by a report on the critical state of educational standards in science and maths in – of all places – Silicon Valley (Goube and Magnavalle, 1984).

To what extent should it be the responsibility of education to co-operate in solving the many problems besetting technological domains such as the Babel tower of computer languages or multitude of operating systems? What is the role and mandate of education with respect to market developments in the electronic manufacturing market? What is the mandate of education on the development of policy for national electronic industries or research? And conversely, what are the responsibilities of industry or research in developing educational response to the technology that are sound for education? What are the responsibilities of non-educational agents in pressing education to establish priorities for technology within a mandate already crowded with tasks yet unfinished, such as those of educating the young in the traditional basic skills and in the respect of social justice?

"Would the world be any better if everyone knew how to program a computer?", the question put by Judah Schwartz encapsulated the dilemma of defining responsibilities for education as well as for other agents currently active at influencing its responses to the technology. Yet the question cannot be avoided nor the answer to it postponed. As one participant at the Conference commented: it would be an evil day for society if men were to lose knowledge and understanding on how computers work.

The conditions whereby educational responses to education will continue to be formulated will no doubt be crucial to achieving final wisdom on the matter. They are not random nor are they self-generated. On the contrary they have to be planned for and monitored for as long as required by the tasks they apply to. They need to be supported continuously and evaluated recurrently. Most of all, they need an overall co-ordination and control that will ensure that education be given the means to fulfill its new mandate while respecting the others. The future of education in a technological world will depend to a large extent on the responsibilities taken by an agent with overall vision, powerful enough to ensure that the rights of the children to be meaningfully educated be respected, legitimate enough to have its directions responded to and resourceful enough to make developments last for as long as needed. Few agencies in the countries could qualify for the task outside their government.

In a number of OECD countries, governments have already taken up the role although few of them have acknowledged their overall long-term responsibilities. The technological revolution affects society as a whole. The interdependence of developments in its various sectors is already acknowledged in policies formulated for education, although it is less so in policies established in other sectors. The role and responsibilities of governments will no doubt remain crucial in the near future to decide on courses of action, by defining objectives for policies and allocating responsibilities and resources for their implementation. In particular, it will remain as its responsibility to see that the interplay between the various agencies, public and private, formal and informal, develops constructively, and that the new objectives possibly established for education continue to reflect the mandate towards its customers.

The new information technologies are the gateway to the society of the future, just as the industrial revolution was to the present one. That transition has improved people's lives in many important respects, but this progress has not been free of costs. There are no reasons to expect that the "technological revolution" will give or take any less. A central question, therefore, is to what extent governments are prepared to use the authority and coverage that they have since gained over economic, social and educational matters to ensure appropriate control over the new developments so that the ultimate balance be a fair one.

Without such explicit and long-lasting commitments of governments to organise the technological market for education, in its broader sense, without loosening institutional and market barriers, without pooling human and material resources, without co-operating across agencies public and private, as well as across national borders the risk is sizeable that resources will be used up for little results. In particular, the introduction of the NIT in education will take longer and will cost more. In the end the doubt remains if it will be carried out at all.

In that case the prediction of the Honourable Bette Stephenson might come true: "if the school cannot assure the role, if it cannot become more skillful and effective in this activity than other agencies of society, there may be little future for school as we know it. If the school serves only as a warehouse for computer terminals, or if it refuses to make use of the technology, it will be bypassed as irrelevant. The computer can operate equally well in the home, in the public library, the office or factory. There must be a reason to go to school and school must accept that fact and meet the challenge, if it is to survive."

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